THE EXPLOSIVES ENGINEER

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The accidental discovery of strange-looking deposits in the salt beds of an ancient sea near Carlsbad, New Mexico, led to prospect drilling in the area, and, eventually, to the development of the rich sylvite beds now being mined. During the past 30 years, the production of potash in the Carlsbad area has become one of the great mining enterprises in North America. It is a $50 million-a-year business furnishing employment to 4,000 people.

Potash Company of America is the biggest producer at Carlsbad. Just now approaching its twenty-first birthday, PCA has made remarkable strides in the development of mining methods, all aimed at getting more ore out of the ground and into its big, modern refinery.

The article beginning on page 135 reviews the history of the potash industry in America. Also, descriptions of the more important operating procedures of Potash Company of America are included.

* * *

Shortly after the introduction of short-period delay detonators in 1946, it became apparent that a given total amount of explosives so detonated often caused appreciably less vibration. Also, the new method often produced more effective fragmentation as compared with a blast fired with the same amount of explosives detonated instantaneously.

Greater breakage from blasting with short-period delay detonators has been explained, in part, by recent high-speed moton pictures of the fracturing of rock by dynamite. The step-by-step release of explosion gases allows initial fractures caused by the gases of one hole to be extended and new ones developed by gases from a succeeding hole.

EDITORIAL STAFF: Joseph I. Horty, *Editor;* Gertrude A. Donnelly, *Assistant Editor;* Elizabeth M. Joyce, *Assistant Editor;* Edward L. Grant, *Art Editor;* Frank J. Canova, *Production Manager;* Charles E. Rabenold, *Advertising Manager;* Montgomery R. Budd, *Director.*

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Views and opinions expressed by the authors of articles in this publication are their own, and they do not necessarily represent those of the publisher.

Experiments have demonstrated that when explosive energy has been applied most efficiently to its job of breaking rock, vibrations are smallest; if vibrations are large, the explosive energy has not been employed with maximum efficiency.

Factual information on this interesting and important new blasting method, illustrated by seismographic recordings, may be found on page 142.

* * *

Uranium in apparently unlimited quantities in the Colorado Plateau is bringing a rush of individuals and capital into the region that promises to surpass the wildest days of the California gold rush in 1849.

In the article "Mining Uranium in the Colorada Plateau," beginning on page 149, Charles F. Thomas describes the weird beauty of the Plateau. For many years it has been a paradise for geologists, artists, and photographers. Today, as a result of the Government's participation in atomic nuclear studies, this heretofore worthless region has apparently become the greatest source of uranium on the American continent, if not in the world.

For Part I of this article on uranium, turn to page 149.

* * *

Erratum: In the article, "Laying a Pipe Line for Canadian Oil Deliveries," published in the July-August, 1954, issue of The Explosives Engineer, we referred to blasting underwater holes in the bed of the Escanaba River with Hercules® 60% Gelatin Extra. This was in error. The grade of dynamite should have been referred to as 60% High-Pressure Gelatin.

We regret that this inaccuracy was not detected before the article was printed.

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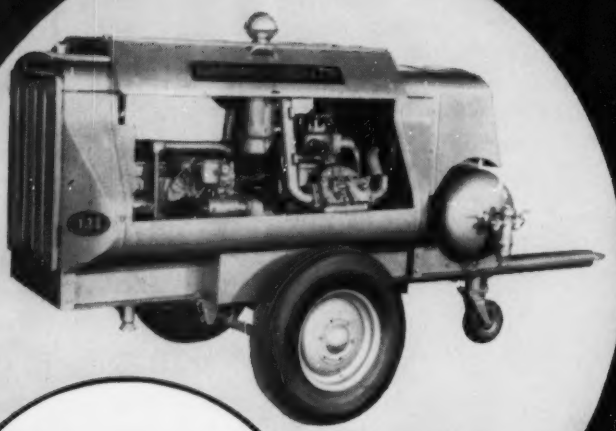
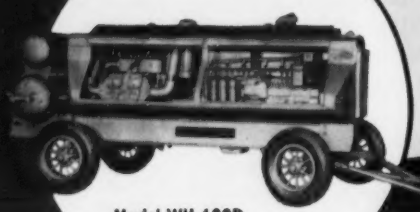


The New Model WH-125



Model WH-600D

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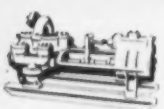
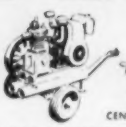


GROUT PUMPS

AIR MOTORS

COMPRESSOR OUTFITS



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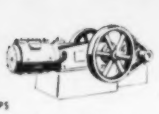
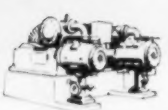
CENTRIFUGAL PUMPS



RX COMPRESSORS



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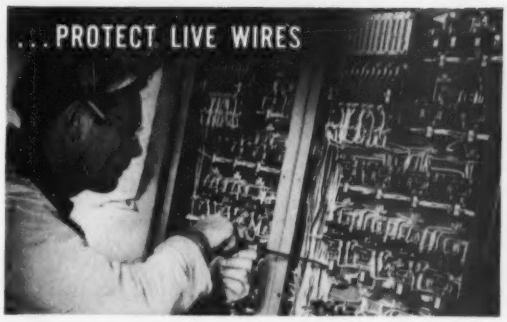

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A Biography

FOLLOWING a course in mining engineering at the Royal Technical Institute in Stockholm, Sweden, in 1906, Julius Bernhard Haffner roamed over Europe for four years working as an engineer and a miner. In 1910, he came to the United States and continued to broaden his knowledge and experience in a wide variety of jobs. In 1940, he became associated with Bunker Hill and Sullivan Mining and Concentrating Company as general manager. Early in 1954, his associates elected him president of the company.

"Barney," as he is known to a wide circle of friends, was born in Dagstorp, Sweden, on Christmas Day in 1886, the son of Mons and Kerstin Person Haffner. He was the youngest in a family of two girls and four boys, who were raised on a small farm owned and operated by their parents in the southern part of Sweden.

Barney received his elementary education in the Dagstorp grade school and the high schools at Landskrona and Lund, Sweden. This was followed by a course in mining engineering at the Royal Technical Institute, a mining college in Stockholm.

His first job was in the iron mines at Dannemora, Sweden, at the age of twenty. He also worked as an engineer and a miner in England, France, Germany, and Russia. In 1910, Barney came to the United States and went to Nome, Alaska, where he washed gold on the Seward Peninsula and the Yukon. Late in 1911, he moved to Illinois and got a job digging coal near Danville. From there he went to Ray, Arizona, and, for the next seven years, worked as shift boss, foreman, and engineer at the mining property of Ray Consolidated Copper Company.

From 1920 to 1923, he was a foreman, engineer, and superintendent with Sheep Creek Gold Mines in California; Western Phosphate Company at Paris, Idaho; Tintic Standard Mining Company at Dividend, Utah; and Park City Consolidated Mining Company at Park City, Utah.

In 1923, Barney went north to Anyox, British Columbia, to take over the duties of general superintendent for Granby Consolidated Mining, Smelting and Power Company. Early in 1926, he went to Sante Fe, New Mexico, to become general manager for American Metal Company of New Mexico. While in New Mexico, he also was a consulting engineer for Real Del Monte Company in Mexico. In the latter part of 1926, he moved to Nevada to become general superintendent for Consolidated Coppermines Corporation at Kimberly; two years later he was made general manager.

In 1940, Barney accepted the position of general manager of Bunker Hill and Sullivan Mining and Concentrating Company at Kellogg, Idaho. In 1954, he was elected to the presidency of the company, the position he now holds.

Mr. Haffner's other business associations include: president of Lead Industries Association, and of Silver Mountain Lead Mines, Inc.; a director of Sullivan Mining Company, Pend Oreille Mines and Metals Company, Reeves-MacDonald Mines Limited, Metaline Contact Mines Company, Silver Ridge Mines Company, and Idaho Custer Mines, Inc. He is a former president and a member of the Idaho Mining Association. He is a former director and a member of A.I.M.E. He is a member and councilor of Mining and Metallurgical Society and a member of the Northwest Mining Association.

Barney's clubs include the Spokane, the Spokane Country, the Shrine, Jester, and Red Cross of Constantine.

Julius Bernhard Haffner married Florence Louise Kinsey on February 8, 1915, in Ray, Arizona. They have two sons, Bernard Kinsey and Robert Louis, both in the mining field. A third son, John Martin, lost his life in the South Pacific during World War II; he had risen from an Army private to a major. The Haffner home is at 1603 East Pinecrest Road, Spokane, Washington.

Barney's hobbies are golf, hunting, and fishing. He indulges his love of fishing at least once a year in joining with friends at a stag outing at Cowichan Bay, British Columbia, to compete for the honor of catching the biggest coho salmon. People in the know say that Barney is a tough competitor in these fishing contests, as he is in everything he tackles.

Editorial

Construction Spearheads Economic Activity

H. E. Foreman, managing director of The Associated General Contractors of America, recently reported that comprehensive surveys indicate the dollar volume of construction work put in place in 1954 is expected to set an all-time record approaching $52 billion. This record figure includes more than $36 billion in new construction and more than $15 billion in maintenance and repairs.

If this forecast is realized, the overall construction volume for 1954 will exceed the 1953 volume by 3 or 4 per cent. It will also mark the ninth consecutive year that the industry has set new records.

Because of increasing public recognition of the country's needs for adequate highways, the largest program in this category in the history of the nation is under way. The volume of work for this type of construction is expected to be approximately $3¾ billion, an increase of at least 15 per cent over the volume for last year.

The significant factor in the 1954 forecast is that more than one dollar in every seven spent for end products and services is being spent for construction. Also, more than 15 per cent of the nation's full-time equivalent employes are receiving their livelihood directly or indirectly through construction activities.

An early survey by the AGC in September, covering 124 of its local chapters, indicates many contractors are convinced that a big year in 1955 is on the way.

As demand pushes the volume toward another all-time peak, the construction industry stands out as the brightest part of the economic picture.

Contractors and manufacturers of construction equipment and materials will be busier than ever to meet the demands of this gigantic program.

Tamp Loaded Drill Holes with Incombustible Stemming

To safeguard workmen in coal mines the U. S. Bureau of Mines conducts various tests of industrial explosives and blasting devices to determine whether the explosives or the devices may be used with safety, and to prescribe the conditions under which they should be used.

The results of these experiments show that two conditions are essential to the safe and permissible use of explosives and blasting devices in coal mines: first, they must be placed in a drill hole and properly primed; second, after a charge is loaded properly, it must be followed with adequate incombustible stemming material tamped firmly to the collar of the drill hole.

Stemming makes blasting operations more efficient by confining the forces released by the blasting action. It also prevents a blown-out shot, with the attending danger of ignition or destructive ricocheting.

In order to conform with the conditions of permissibility as established by the U. S. Bureau of Mines, all permissible explosives and blasting devices fired in coal mines must be adequately confined in drill holes by the use of incombustible stemming material.

Perfect Safety Records

When a large mine or quarry is operated for a year without a lost-time injury the question is often asked: "How do they do it?" A common assumption is that a perfect safety record can be made only by utilizing special methods, skills, or knowledge. But, investigation almost always leads to the same discovery: Safety is an operating problem.

The employment of safety engineers, accident-prevention campaigns, and mechanical safeguards – all accomplish wonders. But, until every supervisory official is persuaded that within his province accident prevention is his personal responsibility, improvement will be limited. Only when every official and every employe accepts this responsibility can perfect safety records be made.

American Mining Congress' Western Meeting

Some 7,000 mining men from all parts of the country and many foreign lands gathered in San Francisco, September 20 through 24, to attend the 1954 Metal and Nonmetallic Mining Convention of the American Mining Congress. Both from the standpoint of attendance and interest, it was the most successful convention in the history of the Western Division of the Congress.

Prominent leaders in Government and industry, as well as technicians and production men in the mining world, addressed the meetings and group forums in the Civic Auditorium on a wide range of subjects. The various sessions provided ample opportunity for discussions of the more important operating, economic, and legislative problems confronting the industry today.

The exhibit of mining equipment and materials, which complemented the technical phases of the convention, presented a comprehensive display of the latest equipment and products of more than 150 manufacturers.

COMPLETING A ROUND: Close-up of a face, with a round of drill holes for blasting almost completed.

POTASH

IN THE CARLSBAD BASIN

From an accidental discovery in 1925, the production of potash in New Mexico has been developed and expanded into a $50-million enterprise

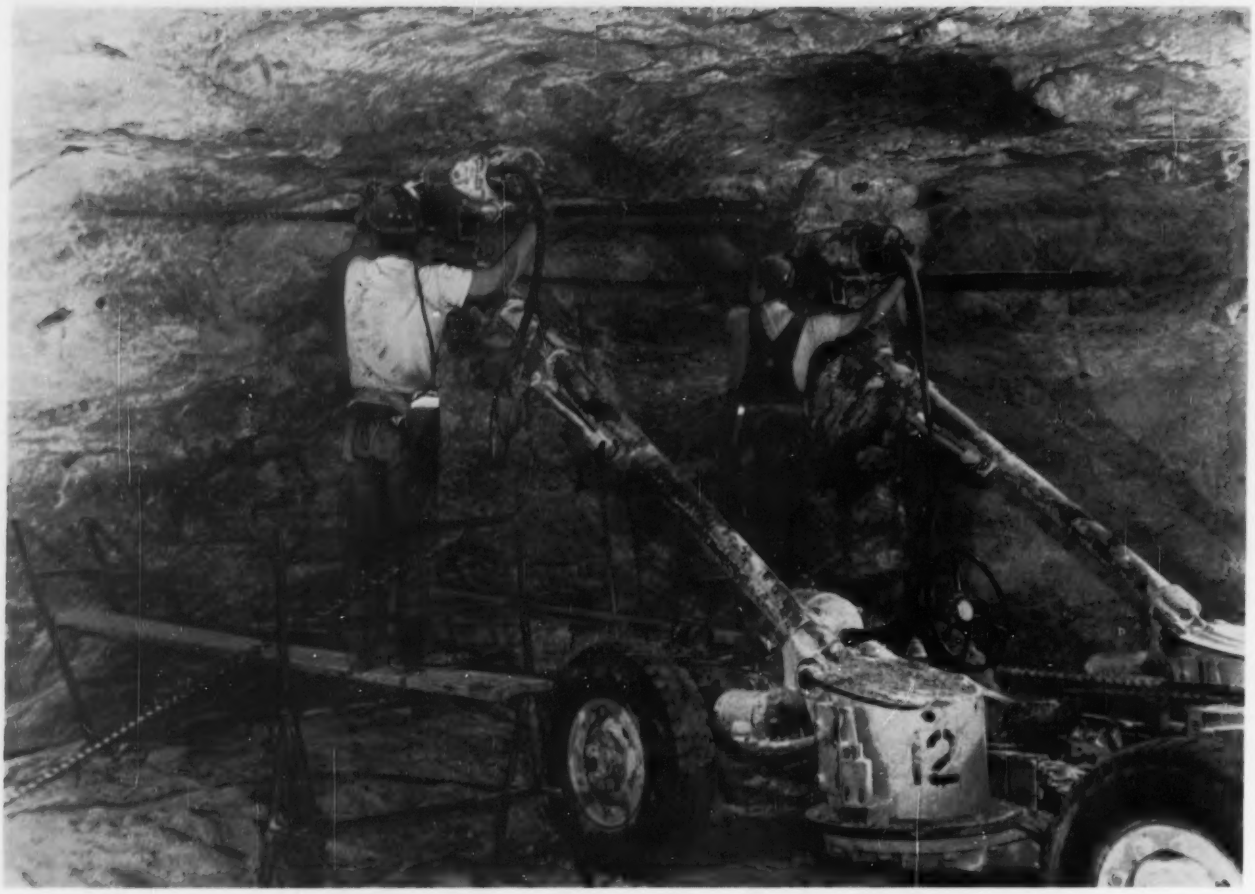
LEWIS NORDYKE*

STARTING with the accidental discovery, in 1925, of pink deposits in the thick salt beds of an ancient sea the production of potash near Carlsbad, New Mexico, has become one of the great mining enterprises of the past 30 years in North America. In that span of time, great strides have been made in the development of mining and refining techniques. The annual domestic output has jumped from practically nothing to just under two million tons of refined potash. And, the young industry is still expanding.

Present production comes close to being a surplus under existing conditions. Potash, designated as K_2O, goes into innumerable chemicals and other products, but its principal use – about 95 per cent – is in commercial fertilizer. Because of drought in wide agricultural regions during the past three years and the decrease in farm income from the postwar boom, the demand for plant food has stabilized. Fortunately, this country, for the first time, has sufficient home-mined potash to meet its needs. This is a radical change from a quarter century ago when the United States depended on imports from Germany.

More than 90 per cent of our national production is from five mines in the area known as the Carlsbad Basin. These mines, each with its own refinery, are operated by Potash Company of America, International Minerals & Chemicals Corporation, United States Potash Company, Duval Sulphur & Potash Company, and Southwest Potash Company (a division of American Metals Company, Ltd.). Aside from this basin, the only potash of any

*2809 Lipscomb Street
Amarillo, Texas



JUMBO DRILLING: For blasting the ore in the face, a round of 30 to 42 holes is drilled 9 ft. deep by the operation of two drills.

LOADING MINE CARS: Joy shuttle cars haul blasted ore from underground working faces to a loading point for transfer into mine cars.

consequence in the Americas comes from salt lake operations at Trona, California, and Bonneville, Utah.

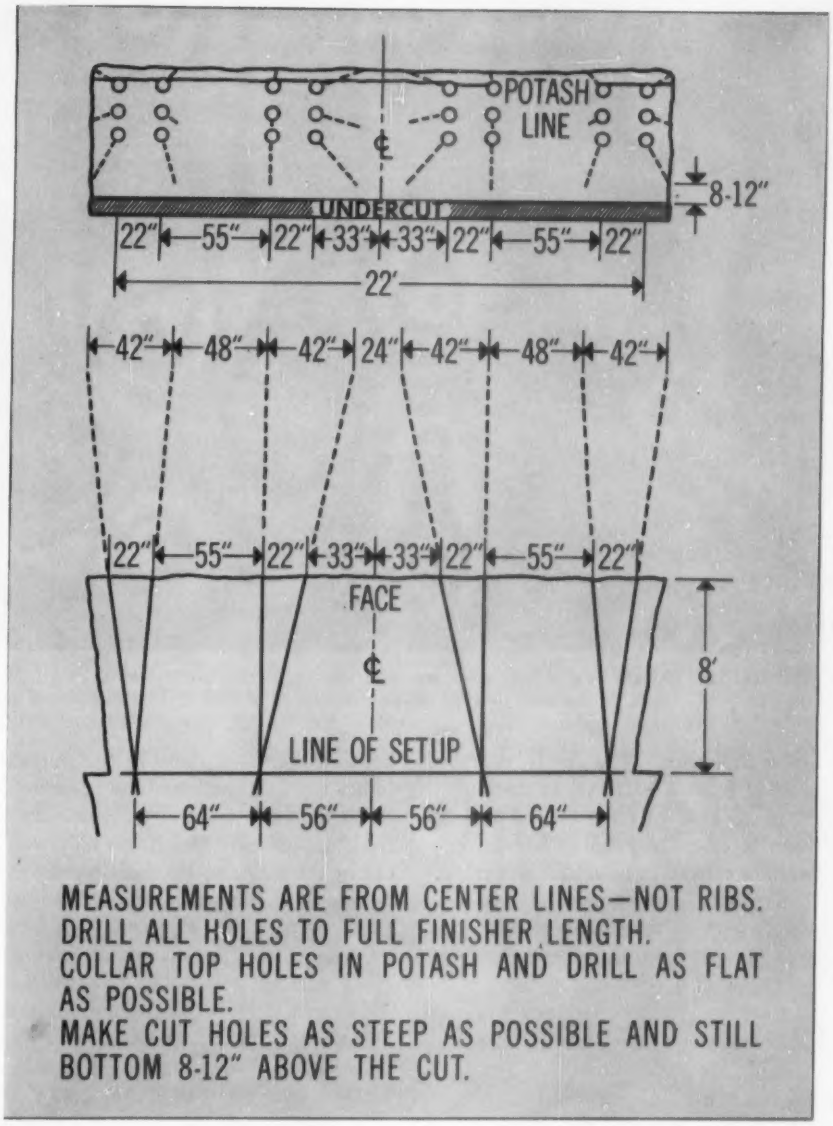
Potash has changed Carlsbad from a tourist town on the banks of the Pecos River, near the portal of Carlsbad Cavern, into a lively industrial center. The cavern attracts about half a million tourists a year. But potash, the biggest mining operation in New Mexico, is a $50 million-a-year enterprise, which furnishes full-time employment to 4,000 persons. The story of the potash industry around Carlsbad is that of a highly progressive mining operation. It is a tribute to the American way of life – free enterprise and venture capital – and the kind of men the American way produces.

Potash Company of America

The biggest producer at Carlsbad is Potash Company of America, a comparatively young stalwart known more familiarly as PCA. It is just now approaching its twenty-first birthday, having started to turn out potash in 1934. It has made remarkable strides in the development of mining methods, all aimed at getting more and more ore out of the ground and into the refinery.

Despite its youth, PCA is a pioneer. The company was organized in Denver in 1930, a time when no one could be positive that potash could be made to pay. Moreover, an economic depression was blighting industry nationwide. At that time, United States Potash Company, the first company to start operations in the basin, was putting down a shaft in an area where vast deposits had been located by core drilling. Likewise, PCA found extensive beds in the salt with exploratory drilling in the fall of 1931. Its first shaft was completed in the spring of 1933, and the production of ore started. The company put its refinery into operation in the fall of 1935. Since that time, the policy of the organization has been one of progress and expansion.

The PCA mine and refinery are located 23 miles northeast of Carlsbad across barren terrain that certainly doesn't appear to be productive of rich fertilizer material. Except for the immediate valley of the Pecos, where water is available for irrigation, the drab, hilly countryside is covered with scrub mesquite. A few farms are scattered about the area, and the land produces well when there is sufficient moisture. The rainfall, at best, is extremely light. The wind sweeps over the rolling hills and on particularly gusty days in springtime it picks up fogs of grit and sand. The elevation is 3,250 ft. above sea level; the slope is gently eastward toward Texas.


POTASH LINE
℄
UNDERCUT
8-12″
22″ 55″ 22″ 33″ 33″ 22″ 55″ 22″
22′
42″ 48″ 42″ 24″ 42″ 48″ 42″
22″ 55″ 22″ 33″ 33″ 22″ 55″ 22″
FACE
℄
8′
LINE OF SETUP
64″ 56″ 56″ 64″
MEASUREMENTS ARE FROM CENTER LINES—NOT RIBS.
DRILL ALL HOLES TO FULL FINISHER LENGTH.
COLLAR TOP HOLES IN POTASH AND DRILL AS FLAT AS POSSIBLE.
MAKE CUT HOLES AS STEEP AS POSSIBLE AND STILL BOTTOM 8-12″ ABOVE THE CUT.

TYPICAL DRILL ROUND: The above diagram shows the location of blast holes in a standard drill round in a 22-ft. face. (Scale – 1 in. equals 5 ft.)

Most of the land is used for grazing cattle and, for the most part, is owned by the Federal Government and the State of New Mexico. The potash companies lease their properties, and Government land regulations limit the number of acres one company can control. As a result, no one company can hold the entire area where potash deposits are known to exist. For this reason, it has been possible for new operators to come into the basin, and more are planning to start, even though it requires large investments of money to get set up for the mining and refining of K_2O.

The headframes and white-smoking stacks of the potash plants extend high up into the sunny sky, giving the lift of life to an otherwise drab landscape. Nevertheless, the area is picturesque and has the feel and the essence of the old frontier West of the cowpoke and the longhorn.

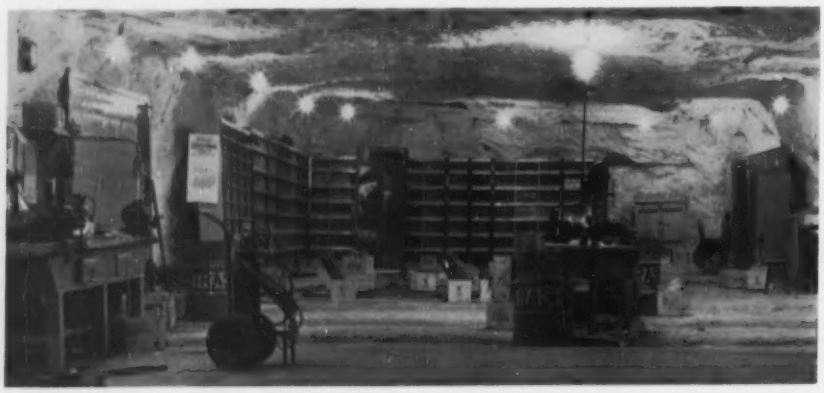
Potash deposits are, on the average,

THE ROTARY DUMP: At the shaft, mine cars with rotating hitches are unloaded by a C. S. Card rotary dump. The dumping deposits the ore onto pan conveyors that carry it to a 36 by 54-in. single-roll Jeffrey primary crusher.

1,000 ft. down. The beds, usually ranging from 3 to 12 ft. in thickness, are in solid salt. Except for the potash, there is essentially no difference between a potash mine and a salt mine. However, the potash and the rock salt, when sawed with undercutters or blasted from the faces with explosives, give the mine the appearance of a pastel-tinted world. The walls of the drifts and the tunnels sparkle like millions of diamonds when the beam from a miner's headlight strikes them.

Carlsbad Cavern, some 50 miles away, is considered one of the wonders of the world. But people who have been in the cavern and in the potash mines say that the man-made burrows in the hard salt are more awesome than the great bat cave which was hollowed out by the action of water on limestone.

The PCA mine has more than 300 miles of tunnels. The company uses the room-and-pillar system of mining, leaving thick pillars to support the overburden. The drifts and tunnels are wide, high, and dry with no trickling water and no fumes. Tunnels can be blasted 8 to 14 ft. high and up to 40 ft. wide without the necessity of supporting timbers. This is because the potash ores were laid down in solid beds, with no structural faults or intruded boulders to cause slips or caves.



ELECTRIC SHOP UNDERGROUND: Blasting is controlled from this electric section in PCA's underground shops. All ordinary maintenance and repairs to mining equipment are taken care of in fully equipped shops in the mine.

The Mining Area

The mining area is a checkerboard of rectangular mined-out rooms and of pillars of ore left as supports. Above the pillars lies a solid bed of rock salt 200 to 700 ft. thick. This, too, was laid down by the evaporating seas of ancient times in a solid unbroken mass, and the great bed of salt acts as a giant beam to support the roof of the mine. As a result, no timbers are needed to make the mine safe, although limited roof bolting is used in some places. There has been no threat of caving. The tunnels, rooms, and pillars are precisely engineered, and safety is emphasized in every operating procedure. A break, if one should occur, could be more dangerous than the average cave in a mine. About 600 ft. above the salt is a veritable ocean of water, which has caused considerable trouble in the sinking of shafts. Should the overburden ever crack sufficiently to let the water pour in, the mine conceivably could go into solution and the recovery of potash would be a thing of the past.

About 400 men work underground in the production of ore in the PCA works. The mine and refinery work on

three shifts, starting at 7 a.m. Largely through the efforts of Russell G. Haworth, vice president in charge of production, PCA has developed continuous mining machines which bore into the ore like mechanical moles. However, the largest percentage of ore production is obtained from blasting the faces with industrial explosives.

PCA uses Sullivan 7B and 10 RU and Goodman 512 undercutters, each with a 9-ft. cutter bar. The 10 RU unit, known as the universal undercutter, is mounted on rubber and is self-propelled. The undercutting provides a second free face to break to and increases the amount of potash that can be pulled per round. Two Chicago Pneumatic drills mounted on a chassis make what PCA calls a Jumbo. With the threader bar turning at 520 r.p.m., a drill can put a hole into the salt at the rate of 65 in. a minute. The double-twist steel is 1½-in. auger-type Kennametal. Detachable tungsten carbide bits are 1¾ in. for starting to drill holes and 1⅝ in. for finishing. The finishing steel is 10½ ft. long, permitting an angled hole to be drilled 9 ft. deep into the face by the drills.

Underground Operations

PCA has developed its own system of face blasting, particularly as to the spacing and angle of the drill holes. In marking and drilling the working faces, the miners follow the potash beds, and the big effort is to get the potash with as little salt as possible. From 30 to 42 holes are drilled 9 ft. deep into the face in vertical rows of 3 or 4, depending on the height of the face, with the rows spaced about 40 in. apart horizontally. In the PCA pattern, the points of the holes should never be over 48 in. apart.

After a round has been drilled, the holes are loaded with Hercomite® 4-X dynamite packed in ⅞ by 8-in. Tamptite® cartridges, together with a primer charge of Hercomite 3-X dynamite in 1 by 8-in. cartridges. The explosives loading ratio is 1.25 to 1.50 lb. of dynamite to a ton of ore in place. Short-period delay electric blasting caps are used to detonate the explosives charges. Blasting circuits are provided for each section and all blasts are fired simultaneously from a central switch at the end of a shift. Results are consistently satisfactory and secondary blasting is seldom required.

Two types of automatic Joy loaders, 11 BU and 14 BU, load the blasted ore into electrically powered rubber-tired Joy shuttle cars. Each car hauls 5 tons to the loading point and unloads into rotary dump-type rail cars. A train of 32 mine cars is pulled on the main haulage line. The working area is 5½ miles across. In one of the mining panels, PCA uses two 36-in. conveyor belts, each 750 ft. long. In this operation, the ore is moved to the belts by shuttle car and conveyed into mine cars on tracks.

Westinghouse 12-ton combination locomotives, powered by battery or trolley, are used on the gathering lines. Westinghouse tandems, two units of 15 tons each, do the heavy work on the main line haulage. At the shaft, the mine cars are unloaded by a C. S. Card rotary dump. The cars, with rotating hitches, do not have to be unhitched for dumping. The dumping is onto pan conveyors that carry the ore to a 36 by 54-in. single-roll Jeffrey primary crusher. From the primary crusher, the ore goes into bins. Link-Belt loaders move it to a skip which lifts it to the surface. The ore is transported by conveyor into gyratory and hammermill-type crushers and then to the refinery. The flotation system is used in separating the potash from the salt.

The end product, almost 100 per cent pure K_2O, is shipped to fertilizer-mixing plants scattered over the nation. As a rule, from one to four trainloads of it roll away from Carlsbad every day of the potash year. Most of it is shipped like wheat — just poured into railroad cars. But some of it is packaged in 100-lb. bags. Whether in bulk or in bags, the loading is automatic. PCA has a good-sized railroad yard and empty cars are rolled alongside the final business end of the plant. The potash spouts out of the refinery into the freight cars.

The tailings, almost pure salt, are dumped into a large, shallow pit. The salt has no commercial value at present. Freight charges to any point would amount to more than the low price the salt would bring.

The Sante Fe Railroad originates the potash freight in Carlsbad, being the only line serving the city. This railroad also operates a 23-mile branch from

SHIFT CHANGE: At shift-change time, the photographer took a picture of some PCA miners leaving the elevator at the bottom of the shaft to go to work in the mines, while others, coming off shift, wait for a ride to the surface.

Carlsbad to the site of the PCA plant.

The administrative offices of Potash Company of America are at the mine and plant site. Its engineers and operating officers live in Carlsbad, except C. K. Boettcher, executive committee chairman, whose home is in Denver. G. F. Coope is president of the company; Fred Davis is vice president and treasurer; Russell G. Haworth is vice president and resident manager in charge of production; R. T. Chapman is assistant resident manager; and Roy Blackman, an attorney, is the industrial relations superintendent. The supervisory personnel includes Ray R. Knill, mine superintendent; E. C. Jourdan, mine engineer; Neal Juhola, general underground foreman; and T. L. Carey, staff engineer.

These men and their contemporaries in the Carlsbad Basin have developed mining and refining methods and techniques which have increased production by vast figures. They have also made the mining of potash one of the cleanest and safest of underground operations. A visitor can make a long tour through the mine and through the crushing, washing, flotation, drying, and loading divisions without soiling his clothes. Volumes of fresh air are pumped from the surface into the PCA mine and pressured into every nook and cranny of the working areas. The operating areas are free from noxious gases and explosive dusts. The temperature is a constant 74 degrees.

Fresh Air a Problem

The circulation of fresh air led to one of the biggest problems PCA has faced. In order to carry air to every part of the mine effectively, PCA needed a second shaft. Also, a second opening was essential to faster operations all around.

In sinking this shaft, Winston Brothers Company, the contractor on the job, encountered water lying above the salt bed. The water gushed in, work had to be stopped, and resort to the usual methods failed to control the flow. PCA's Vice President Russell G. Haworth hurried off to England, France, and Belgium where he investigated shafts that had been sunk by a system of freezing underground water. Although this method had been used in Germany before the turn of the century, it had not been tried at any important shaft-sinking projects in the United States.

When Haworth returned, plans for freezing the water were worked out by engineers of PCA and Winston Brothers. All of the European shafts that had been sunk by the freezing method had been lined with heavy iron pipe. But PCA decided to use reinforced concrete instead of pipe, and it worked.

The freezing of the water was accomplished by drilling 30 holes around the circumference of the shaft down to the water strata and then pumping refrigerant into the trouble zone. After the water was frozen, it was relatively easy to continue the shaft-sinking operations and to complete the job successfully.

CHIEF ADMINISTRATIVE OFFICER: The Potash Company of America's president and chief administrative officer is George Frederick Coope.

PCA maintains mechanical and electrical repair shops underground in the mine and on the surface. The underground unit takes care of all ordinary repairs on mining equipment, and only jobs that require major reconditioning are taken above ground to the large, fully equipped machine shop. All power within the mine is electrical. Some potash operators in the area have succeeded in using a limited number of diesel units underground by scrubbing the exhaust, but PCA has not tried this. PCA generates most of its power but, recently, it tied into the lines of Southwestern Public Service Company for additional current.

The Storage Problem

Within the past year, PCA faced a brand-new problem – storage. In its early years, during World War II, and in the postwar expansion of agriculture, PCA's big job was to try to keep abreast of the growing demand for potash. Every ton that came out of the refinery went direct into rail cars for shipment to fill standing orders.

In those days potash was relatively scarce, and fertilizer dealers bought

DIRECTORS OF OPERATIONS: Russell G. Haworth, left, is PCA's vice president and resident manager in charge of production. Ray R. Knill, right, is superintendent in charge of the company's underground operations.

and stocked it throughout the year to insure having adequate supplies. Now, with plenty of potash available, the fertilizer trade has adopted a seasonal pattern of buying in the late winter and early spring months. This has had considerable effect on the potash operations in the Carlsbad Basin. The February 1 to May 31 period is the heavy-shipping season. From June 1 to February 1, a substantial percentage of production goes into storage.

This changed buying practice has required the construction of additional storage facilities to carry the heavier inventories, and all of the producing companies have had to expand warehouse space. The combined cost of these additional storage warehouses has run into several millions of dollars. Naturally, the use of these new storage facilities requires more handling, which increases overall costs.

The new order of things has brought about a changed picture from that of not many years ago. The problem then was to obtain an adequate supply of potash at a price that was not prohibitive. This situation had existed from colonial days when potash was produced from wood ashes. As the Eastern forests were cut, this source of supply was reduced. The discovery of potash in Germany in 1843 (from deposits laid down at the same time as those in the Carlsbad Basin), and the development of the industry by 1861, put an end to the wood ash business as a major enterprise in the United States.

The German potash industry was the sole source of supply for American agriculture and industry up to the outbreak of World War I. This country's complete dependence on Germany was brought home with a wallop in 1910, when, as a result of the reorganization of the German potash industry, favorable contracts held by American importing concerns were cancelled. The raising of prices by the German cartel led Congress, in 1911, to appropriate money for the Agriculture and Interior Departments to investigate possible potash sources in this country. However, imports continued until 1914, when the outbreak of war cut off supplies and American agriculture was left without this necessary plant food.

The United States resorted to a multitude of expensive sources, such as brine lakes, distillery wastes, flue dust, and seaweeds. The price zoomed from $35 a ton to $500. When the war ended and German potash again came to America, the great majority of the 128 producing units that had been developed ceased operations. They could not compete with the lower priced imported product.

But the war-time shortage had been almost tragic and some people refused to forget the lesson from the war. They insisted that safety for this country as far as potash was concerned could lie only in the discovery and the distribution of low-cost American supplies.

Exploratory core drilling was carried on by the United States Geological Survey in widely scattered parts of the country, but the first commercial deposit was discovered quite unexpectedly by private interests.

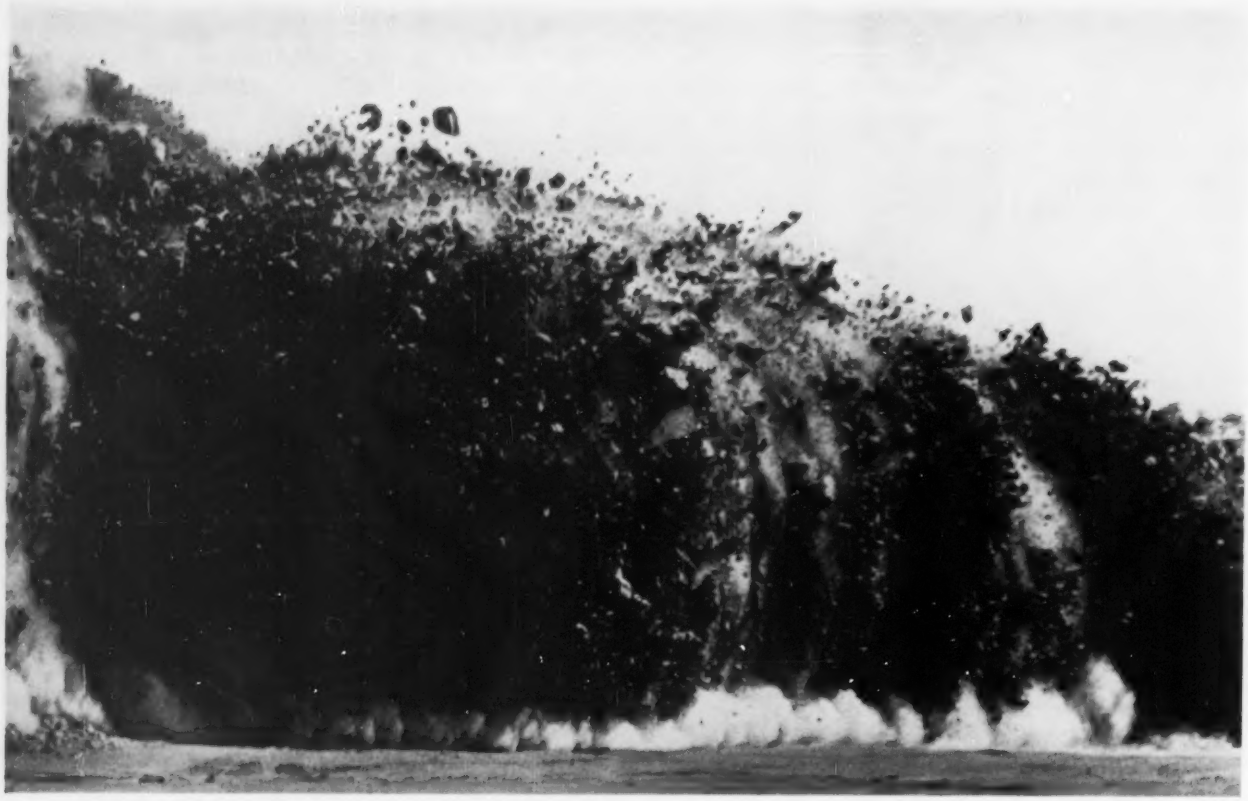
Accidental Discovery

In 1925, the Snowden & McSweeney Company was drilling a wildcat well in search of oil 25 miles northeast of Carlsbad. Strange-looking stuff came out in the slush from the drilling operations. Tested, it proved to be potash. The try for oil failed, but Snowden & McSweeney became the United States Potash Company, which started core drilling. This exploration established that there were deposits of sufficient promise to warrant the sinking of a shaft. The principal potash-bearing material found was sylvite, a mixture of potassium chloride and sodium chloride, containing from 21 to 25 per cent K_2O.

When U. S. Potash started sinking its shaft, the stock market had crashed and the economy of the country was in a tail spin. Before that first venture could be proved, Potash Company of America was organized to find, mine, and refine potash.

(Continued on page 155)

PCA'S REFINERY: After the ore is lifted to the surface in a skip, it is moved on a conveyor to gyratory and hammermill-type crushers, and to the refinery. In the refinery, the flotation system separates the potash from the salt.



QUARRY BLASTING

With Short-Period Delay Detonators

Extensive experiments show that, in most cases, quarry blasts fired with short-period delay detonators result in more effective fragmentation and appreciably less vibration

L. DON LEET*

After short-period delay detonators were introduced in quarry blasting about 1946, it became apparent that a given total amount of explosives detonated in this manner often caused appreciably less vibration. In addition, the new method often produced more effective fragmentation as compared with a blast fired with the same amount of explosives detonated instantaneously. However, these results were not invariably attained and much work has been done in the intervening years by technical representatives of explosives manufacturers, seismologists, and quarry operators to determine the controlling factors. These factors include type of hole, amount of explosives per hole or delay interval, burden and spacing, number of delay detonators used, order of firing, explosives loading ratio or powder factor, and a number of other variables.

*Chairman, Division of Geological Sciences, Harvard University, Cambridge 38, Mass.

Capacity of Vibrations For Causing Damage

Seismographic measurements of the vibrations produced by this method of blasting have proved to be the most effective check on the results of experi-

mentation. The interpretation of such measurements has involved investigation of features of vibrations that give a direct measure of the capacity of the vibrations for damaging structures or structural materials.

Edward H. Rockwell, a pioneer in the seismographic study of vibrations from blasting, pointed out that the essential feature for determining the capacity for doing damage is the kinetic energy,[1] which is proportional to f^2A^2, where f is frequency and A is amplitude. This is the same as saying kinetic energy, or capacity for doing work, is proportional to v^2, where v is the velocity with which the vibration moves a structure.

To illustrate the value of kinetic energy in contrast to acceleration as an indicator of damage capacity, Rockwell compared the effects on a house computed for vibrations from a dynamite blast and vibrations from an earthquake, where computed acceleration in each case was 0.3 g. (three-tenths the acceleration produced by gravity). Kinetic energy from the dynamite blast was 67 in./lb. and from the earthquake 15,100 in./lb. Displacement from the blast was 0.009 in., but from the earthquake vibrations it was 2.03 in. The earthquake caused damage, but the vibrations from the dynamite blast did not cause any damage.

F. J. Crandell[2] followed this line of reasoning in establishing a quantity he called energy ratio, E. R., also proportional to kinetic energy, hence to v^2. E. R. $= a^2/f^2$ where a is acceleration in ft./sec.^{2} and f is frequency in cycles/sec. If measurements are made on a seismograph which records displacement, such as the Leet portable three-component unit, a convenient expression for energy ratio is E. R. $= 10.8\ f^2A^2$, where A is amplitude in inches.

Crandell took the essential step of establishing limits for the value of E. R. based on actual experiment. He concluded, "An investigation of over 1,000 residential homes, stores of two stories in height, some schools, churches, and hospitals, which were investigated before the disturbance or vibration occurred and after the vibration occurred, shows that if the energy ratio is kept below 3 there will not be damage to buildings of average workmanship and good materials." Some old, prestressed structures may be subjected to minor damage if the energy ratio exceeds 3. If it exceeds 6, damage may be expected in any structure.

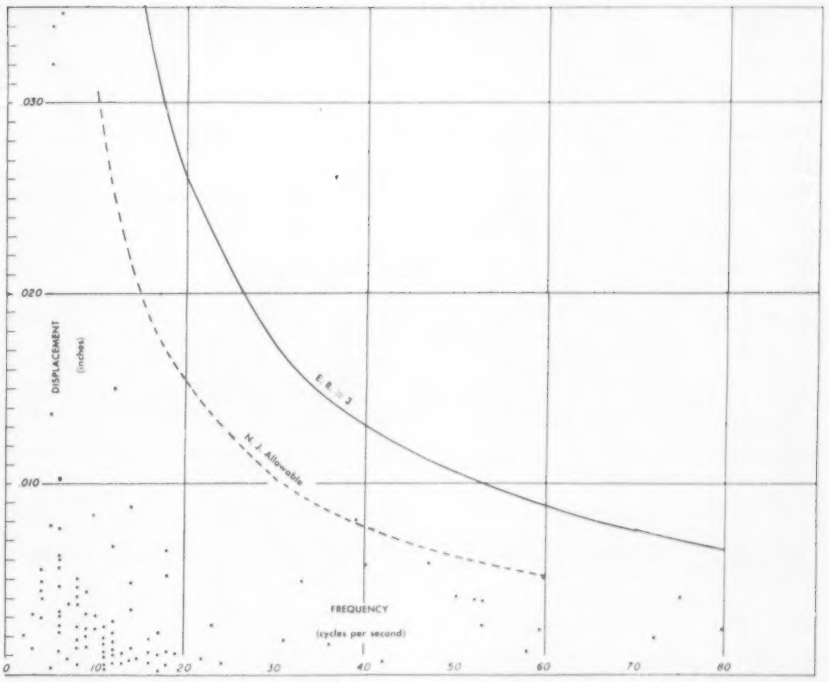


FIGURE 1: Combinations of frequency and amplitude which produce an energy ratio of 3, and the allowable limits of vibration in the State of New Jersey. The dots represent typical observations from commercial blasting operations.

Figure 1 shows the combinations of frequency and amplitude which produce an energy ratio of 3. Also plotted on it is a line representing allowable limits of vibration in the State of New Jersey. A few points representing actual observations are added to show how far the great majority of vibrations from commercial blasting operations fall below the amounts necessary to present any hazard of structural damage. These points on Figure 1 are fairly representative of thousands of observations throughout the country

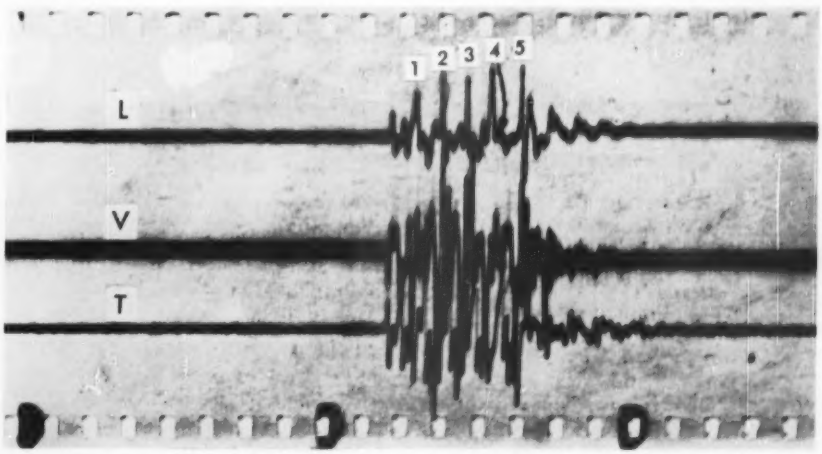


FIGURE 2: Accelerations recorded 400 ft. from a five-hole blast in which each hole was detonated 0.025 sec. after the one before it. The greatest force which went into the formation of vibrations was that applied by the explosives detonated by a single delay interval.

[1]Edward H. Rockwell, "Vibrations Caused by Blasting and Their Effect on Structures," 69 pp., Hercules Powder Company, Wilmington, Delaware, 1934.

[2]F. J. Crandell, "Ground Vibration Due to Blasting and Its Effect Upon Structures," *Jour. Boston Soc. Civ. Engrs.*, 222-245, Apr., 1949.

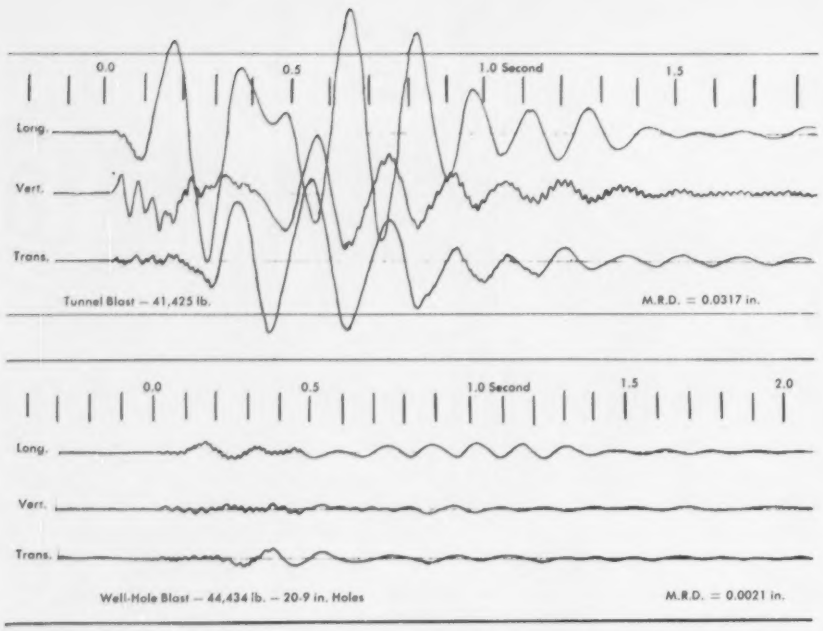


FIGURE 3: This is a record of vibrations from a coyote tunnel blast fired with instantaneous detonators as compared with the vibrations from a greater total amount of explosives distributed among 20 well-drill holes, 9 in. in diameter, fired with 0.026-sec. delay between holes. Recorded on a Leet seismograph by Ranald Jones.

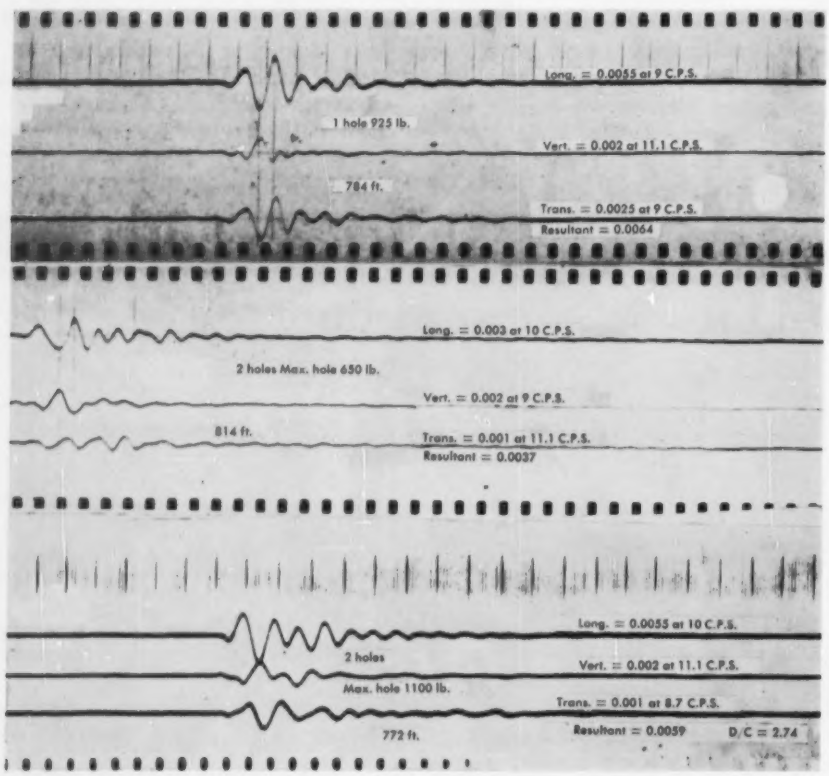

Long. = 0.0055 at 9 C.P.S.
1 hole 925 lb.
Vert. = 0.002 at 11.1 C.P.S.
784 ft.
Trans. = 0.0025 at 9 C.P.S.
Resultant = 0.0064
Long. = 0.003 at 10 C.P.S.
2 holes Max. hole 650 lb.
Vert. = 0.002 at 9 C.P.S.
814 ft.
Trans. = 0.001 at 11.1 C.P.S.
Resultant = 0.0037
Long. = 0.0055 at 10 C.P.S.
2 holes
Vert. = 0.002 at 11.1 C.P.S.
Max. hole 1100 lb.
Trans. = 0.001 at 8.7 C.P.S.
772 ft.
Resultant = 0.0059
D/C = 2.74

FIGURE 4: Records for Lines 1, 2, and 3 in Table I, as recorded on a Leet seismograph by J. Birch.

by specialists in the study of vibrations.

Well-drill Delay Firing — Mechanism of Reduction of Vibration

From the beginning of these investigations, it was apparent that the ultimate realization of the full potentialities of short-period delay firing would be possible only when a complete explanation could be found for the mechanism by which breakage was improved and vibrations at distant points were reduced. Important clues to this explanation have been developed from recent practical developments in this field.

One line of evidence has come from the records of seismographic instruments that measure acceleration directly. These records supply details in the vibration picture close to quarry blasts. Figure 2 shows such a record obtained by Crandell. This was taken approximately 400 ft. from a five-hole blast in which the explosives charge in each hole was detonated 0.025 sec. after the one before it was fired. It shows the acceleration produced by each hole as a separate event, indicating that the greatest force (force equals mass times acceleration) devoted to generating vibrations at any instant was that developed by the explosives in a single hole. The ground motion smooths out very quickly into more regular, rhythmic oscillations, but it never exceeds in amount a maximum that is produced by the explosive energy of a single-delay firing interval.

Obviously there must be a delay interval too short to accomplish such separation in the application of impact to the ground for creating vibrations. Figure 2 shows the results of an interval of 0.025 sec. with a hole spacing of 22 ft. A blast fired with instantaneous detonators would be the other extreme. At present, we cannot say at just what point between these two lies an interval too short to produce significant benefits from short-period delay firing. It seems highly probable that 0.005 sec. is too short, and 0.010 sec. may be, but this has not been demonstrated conclusively. One quarry operator who conducted an extensive series of tests to determine the optimum firing interval for his quarry concluded that it was between 0.035 sec.

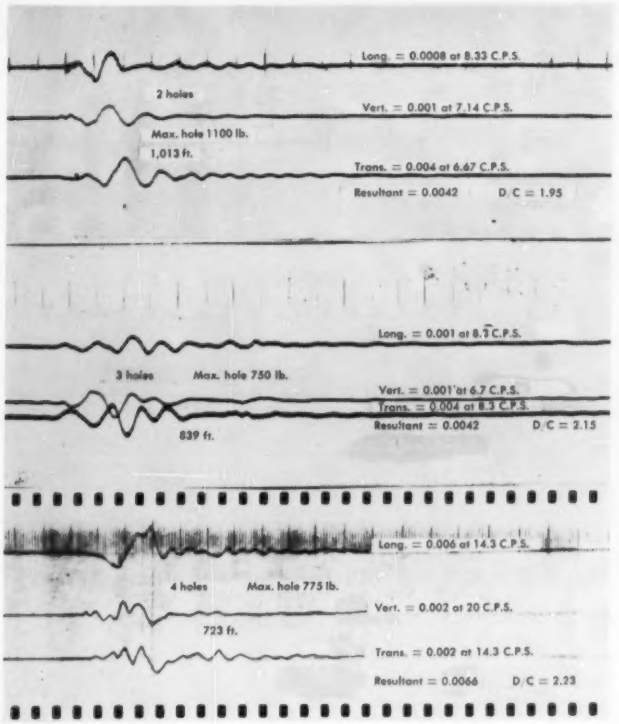

Long. = 0.0008 at 8.33 C.P.S.
2 holes
Vert. = 0.001 at 7.14 C.P.S.
Max. hole 1100 lb.
1,013 ft.
Trans. = 0.004 at 6.67 C.P.S.
Resultant = 0.0042 D.C = 1.95
Long. = 0.001 at 8.3 C.P.S.
3 holes Max. hole 750 lb.
Vert. = 0.001 at 6.7 C.P.S.
Trans. = 0.004 at 8.3 C.P.S.
839 ft.
Resultant = 0.0042 D.C = 2.15
Long. = 0.006 at 14.3 C.P.S.
4 holes Max. hole 775 lb.
Vert. = 0.002 at 20 C.P.S.
723 ft.
Trans. = 0.002 at 14.3 C.P.S.
Resultant = 0.0066 D.C = 2.23

FIGURE 5: Records for Lines 4, 5, and 6 in Table I, as recorded on a Leet seismograph by J. Lutz and J. Birch.

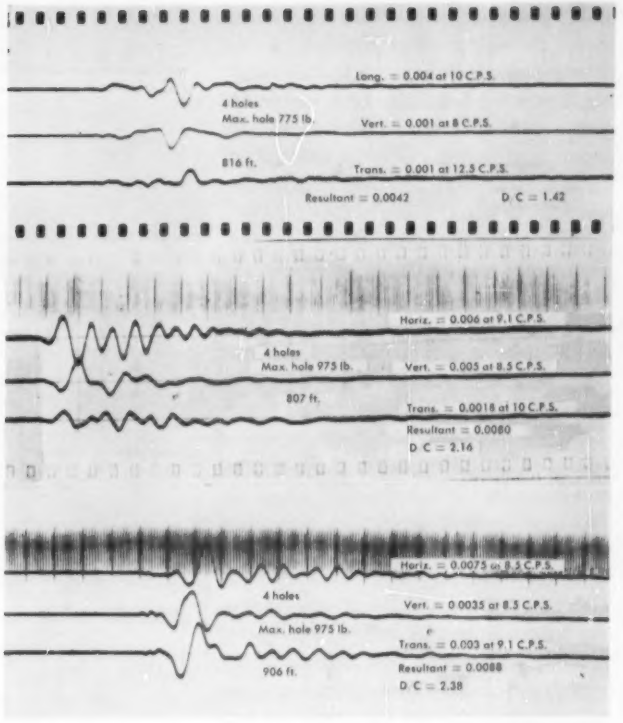

Long. = 0.004 at 10 C.P.S.
4 holes
Max. hole 775 lb.
Vert. = 0.001 at 8 C.P.S.
816 ft.
Trans. = 0.001 at 12.5 C.P.S.
Resultant = 0.0042 D.C = 1.42
Horiz. = 0.006 at 9.1 C.P.S.
4 holes
Max. hole 975 lb.
Vert. = 0.005 at 8.5 C.P.S.
807 ft.
Trans. = 0.0018 at 10 C.P.S.
Resultant = 0.0080
D.C = 2.16
Horiz. = 0.0075 at 8.5 C.P.S.
4 holes
Vert. = 0.0035 at 8.5 C.P.S.
Max. hole 975 lb.
Trans. = 0.003 at 9.1 C.P.S.
906 ft.
Resultant = 0.0088
D.C = 2.38

FIGURE 6: Records for Lines 7, 8, and 9 in Table I, as recorded on a Leet seismograph by G. Gehling, R. Kirpa, and J. Birch.

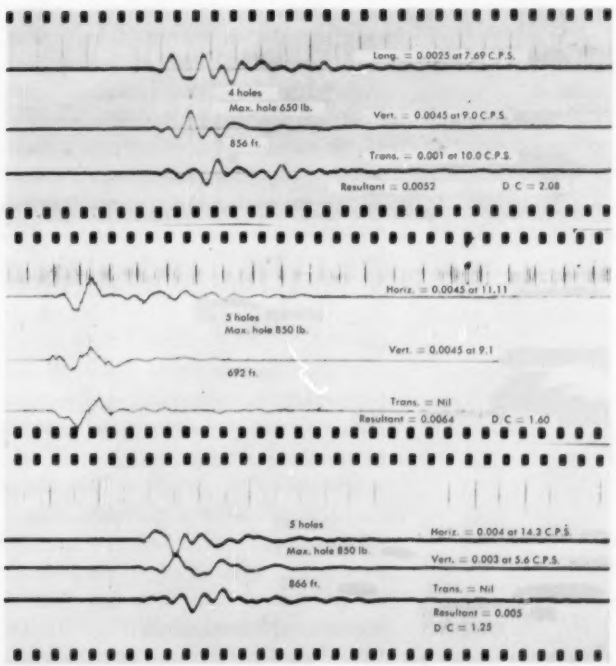

Long. = 0.0025 at 7.69 C.P.S.
4 holes
Max. hole 650 lb.
Vert. = 0.0045 at 9.0 C.P.S.
856 ft.
Trans. = 0.001 at 10.0 C.P.S.
Resultant = 0.0052 D.C = 2.08
Horiz. = 0.0045 at 11.11
5 holes
Max. hole 850 lb.
Vert. = 0.0045 at 9.1
692 ft.
Trans. = Nil
Resultant = 0.0064 D.C = 1.60
5 holes
Horiz. = 0.004 at 14.3 C.P.S.
Max. hole 850 lb.
Vert. = 0.003 at 5.6 C.P.S.
866 ft.
Trans. = Nil
Resultant = 0.005
D.C = 1.25

FIGURE 7: Records for Lines 10, 11, and 12 in Table I, as recorded on a Leet seismograph by R. Kirpa, F. Woodruff, and J. Birch.

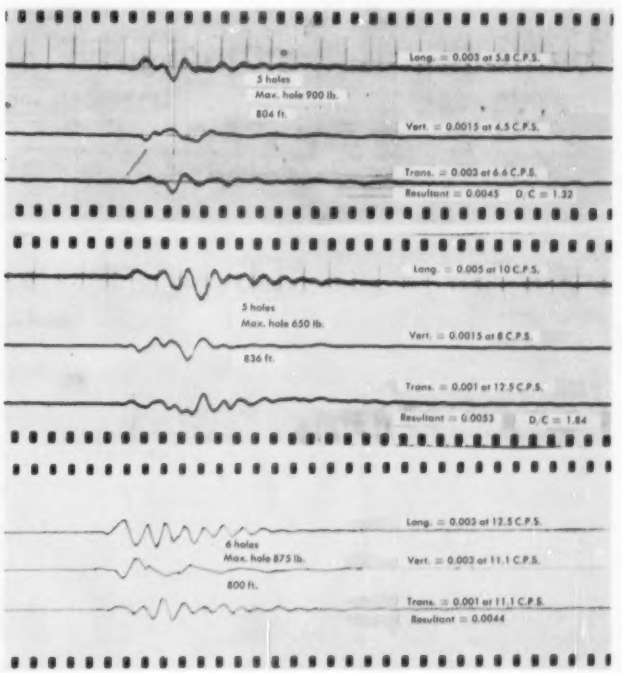

Long. = 0.003 at 5.8 C.P.S.
5 holes
Max. hole 900 lb.
804 ft.
Vert. = 0.0015 at 4.5 C.P.S.
Trans. = 0.003 at 6.6 C.P.S.
Resultant = 0.0045 D.C = 1.32
Long. = 0.005 at 10 C.P.S.
5 holes
Max. hole 650 lb.
Vert. = 0.0015 at 8 C.P.S.
836 ft.
Trans. = 0.001 at 12.5 C.P.S.
Resultant = 0.0053 D.C = 1.84
Long. = 0.003 at 12.5 C.P.S.
6 holes
Max. hole 875 lb.
Vert. = 0.003 at 11.1 C.P.S.
800 ft.
Trans. = 0.001 at 11.1 C.P.S.
Resultant = 0.0044

FIGURE 8: Records for Lines 13, 14, and 15 in Table I, as recorded on a Leet seismograph by R. Kirpa and J. Birch.

and 0.040 sec. In general, experience seems to indicate that a delay of approximately 0.001 sec. per foot of spacing is not far from the best for many quarries using well-drill blast holes. As a practical matter, a delay interval of 0.025 sec. seems to be very effective for spacings in the vicinity of 20 ft.

This observation of the vibration-generating impact from each delay interval as a separate event confirms part of one earlier theory as to the mechanism by which short-period delay detonators reduce vibrations. It shows that the differences from firing with instantaneous detonators are introduced at the source and do not result from the interference and cancellation of waves after they are generated.

Greater breakage from blasting with short-period delay detonators has been explained in part by recent high-speed motion pictures of the fracturing of rock by dynamite. These pictures show that rupture may be initiated in a few milliseconds but not completed for several hundred milliseconds. The step-by-step release of explosion gases allows initial fractures caused by the gases of one hole to be extended and new ones developed by gases from a succeeding hole.

A general principle of importance is that vibrations are waste by-products of the blasting operation. When explosive energy has been applied most efficiently to its job of breaking rock, vibrations are smallest. By the same token, if vibrations are large the explosive energy has not been employed with maximum efficiency.

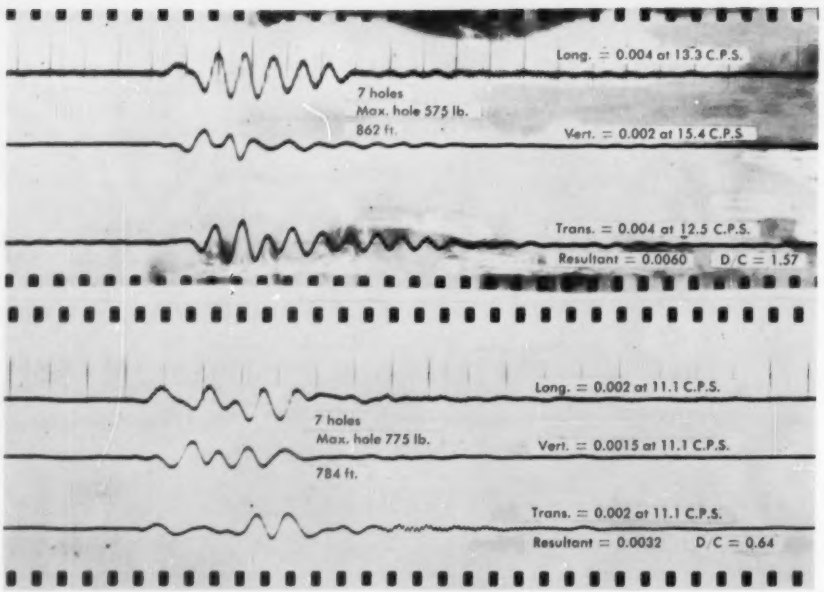

Long. = 0.004 at 13.3 C.P.S.
7 holes
Max. hole 575 lb.
862 ft.
Vert. = 0.002 at 15.4 C.P.S.
Trans. = 0.004 at 12.5 C.P.S.
Resultant = 0.0060 D.C = 1.57
Long. = 0.002 at 11.1 C.P.S.
7 holes
Max. hole 775 lb.
784 ft.
Vert. = 0.0015 at 11.1 C.P.S.
Trans. = 0.002 at 11.1 C.P.S.
Resultant = 0.0032 D.C = 0.64

FIGURE 9: Records for Lines 16 and 17 in Table I, as recorded on a Leet seismograph by R. Kirpa and J. Birch.

Well-drill Delay Firing — Contrast with Coyote Tunnel

Although it has been well established that firing blasts with delay detonators reduces the vibrations generated by a given total amount of explosives, the spectacular extent to which this can be true is not always realized. Figure 3 shows an example of this. Blasts containing comparable amounts of total explosives were fired in the same quarry and recorded at the same location. The top record in Figure 3 shows displacements from instantaneous detonation in a tunnel blast, and the bottom record shows displacements from the firing of explosives distributed among 20 holes 9 in. in diameter, detonated in sequence with 0.026-sec. delay between holes. In the tunnel blast, the detonation of 41,425 lb. of explosives caused a maximum resultant displacement of 0.0317 in. In the well-drill blast, the firing of 44,434 lb. of explosives caused a maximum resultant displacement of 0.0021 in., less than 7 per cent of the tunnel's.

TABLE I
EFFECTS OF INCREASING NUMBER OF WELL HOLES
(Records in Figures 4-9)

Line	*Fig.*	*No. Holes*	*Max. lb. per hole*	*Powder Factor tons/lb.*	*Distance ft.*	*Max. Resultant Displacement in.*
1	4	1	925	5.6	784	0.0064
2	4	2	650	4.6	814	.0037
3	4	2	1100	4.73	772	.0059
4	5	2	1100	4.73	1013	.0042
5	5	3	750	5.17	839	.0042
6	5	4	775	4.81	723	.0066
7	6	4	775	4.81	816	.0042
8	6	4	975	4.98	807	.0080
9	6	4	975	4.98	906	.0088
10	7	4	650	4.59	856	.0052
11	7	5	850	4.58	692	.0064
12	7	5	850	4.58	866	.0050
13	8	5	900	5.02	804	.0045
14	8	5	650	4.78	836	.0053
15	8	6	875	4.88	800	.0044
16	9	7	575	4.50	862	.0060
17	9	7	775	5.00	784	.0032

Well-drill Delay Firing Optimum Number of Holes

For reasons that are not entirely clear, the effectiveness of delay firing in reducing vibration and increasing efficiency seems at times to be greatest for blasts of a certain optimum number of holes. As would be expected, the maximum explosives fired on a single delay interval is a factor but there is some unexplained effect in addition to this. Usually, there are so many variables involved that it is difficult to isolate this effect clearly, but the data

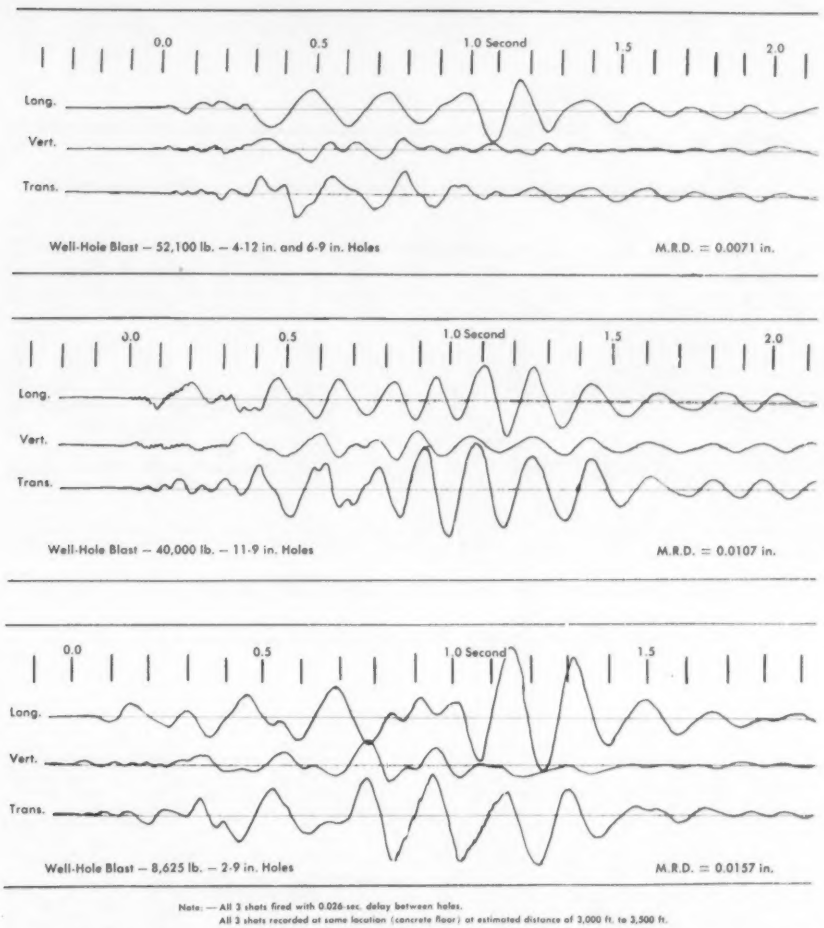


FIGURE 10: Comparison of ten-hole, eleven-hole, and two-hole delay blasts, as recorded on a Leet seismograph by Ranald Jones. M.R.D. = maximum resultant displacement.

summarized in Table I illustrate some of the features of the problem.

The data shown in Table I represent a systematic attempt to determine the optimum number of holes at a quarry where blasting was for awhile limited to one hole at a time because of vibration complaints and a general request by local officials to "cut down on the shooting."

Line 1 gives data typical of the one-hole blasting. Line 3 shows essentially similar displacements at a comparable distance from a two-hole delayed blast with a maximum of 1100 lb. of dynamite in one hole as contrasted with a blast of 925 lb. in the single hole.

Lines 6 and 7 represent records at two distances from one blast. By interpolation, the displacement was 0.0050 in. at 784 ft. If the motion were directly proportional to the maximum explosives per hole, this would have been 0.0060 in. for the 925 lb. of Line 1.

Similar computations for the five-hole blast in Lines 11 and 12 show that it represents 0.0062 in. at 784 ft. for a maximum of 925 lb. of dynamite per hole, as compared with the 0.0064 in. of Line 1.

Therefore, from one-hole through five-hole blasts, delay firing was, in effect, producing an amount of vibration not significantly different from the amount to be expected from the most heavily loaded hole fired alone.

Lines 16 and 17 represent seven-hole blasts that are in striking contrast with each other and with all other blasts of the series. Line 16 represents motion that would have been about 0.0102 in. at 784 ft. with a maximum of 925 lb. of dynamite in one hole. This is the largest motion of the series. The motion of Line 17 would have been 0.0038 in. at 784 ft. for 925 lb. maximum in one hole. This is the smallest motion of the series, by a significant margin.

One difference between the blasts in Lines 16 and 17 was the powder factor. But there were other blasts, such as the one in Lines 8 and 9, where a powder factor similar to that of Line 17 did not prevent development of relatively large vibrations. For some unexplained reason or reasons, the blast in Line 17 was strikingly the most efficient of the series. Inspection of the character of the vibratory motion for Lines 16 and 17, shown on Figure 9, suggests the possibility that some of the holes for the blast in Line 16 got "into step," although the delay interval and spacing were presumably the same as for the blast in Line 17. If this did happen, the effective maximum explosive per delay interval would have been increased.

Figure 10 shows three records taken at another quarry for the purpose of investigating this matter of optimum number of holes and the powder factor. At this quarry, blasts were once limited to two holes each on the theory that this would minimize vibrations. Going from two holes and a total of 8,625 lb. of dynamite to 11 holes and a total of 40,000 lb. of dynamite reduced the maximum resultant displacement

(Continued on page 154)

TABLE II
DATA FOR BLASTS ILLUSTRATED IN FIGURE 11

	Blast Location	*No. Holes*	*Total Explosives lb.*	*No. Delays*	*f*	*A in.*	*E.R.*
Top Record	Top of Face	61	1,850	8	5	0.0076	0.016
					75	0.0041	1.215
			Distance to seismograph, 250 ft.				
Bottom Record	120 to 144 ft. below top of face	67	2,100	8	6	0.0063	0.016
					33	0.0049	0.235
			Distance to seismograph, 260 ft.				

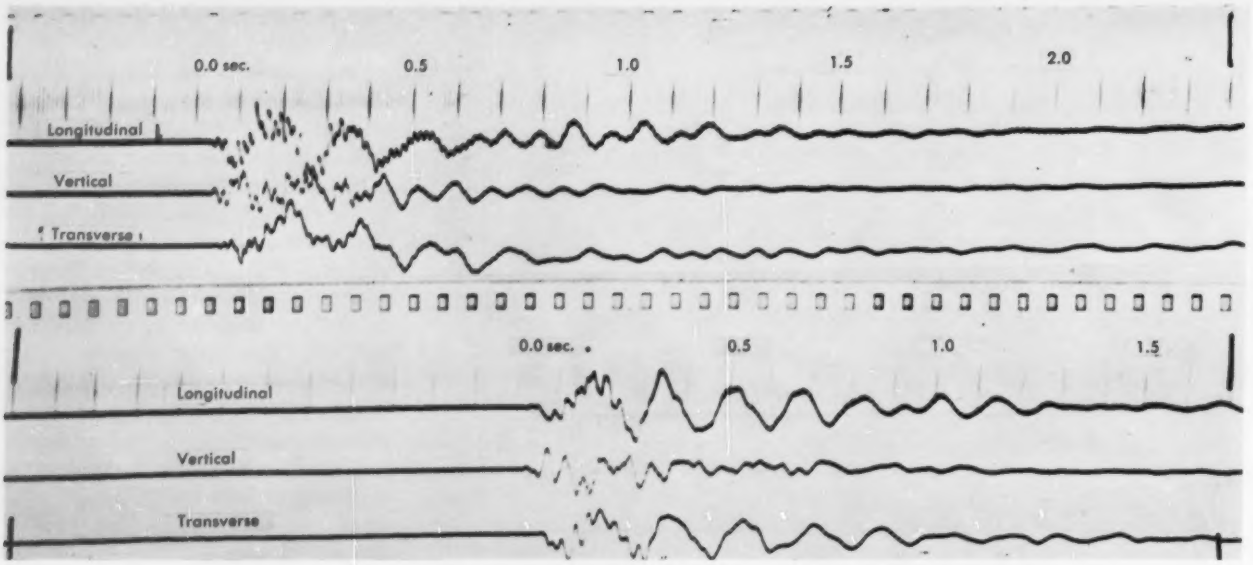


FIGURE: 11: Records for data in Table II, as recorded on a Leet seismograph by Philip Berger.

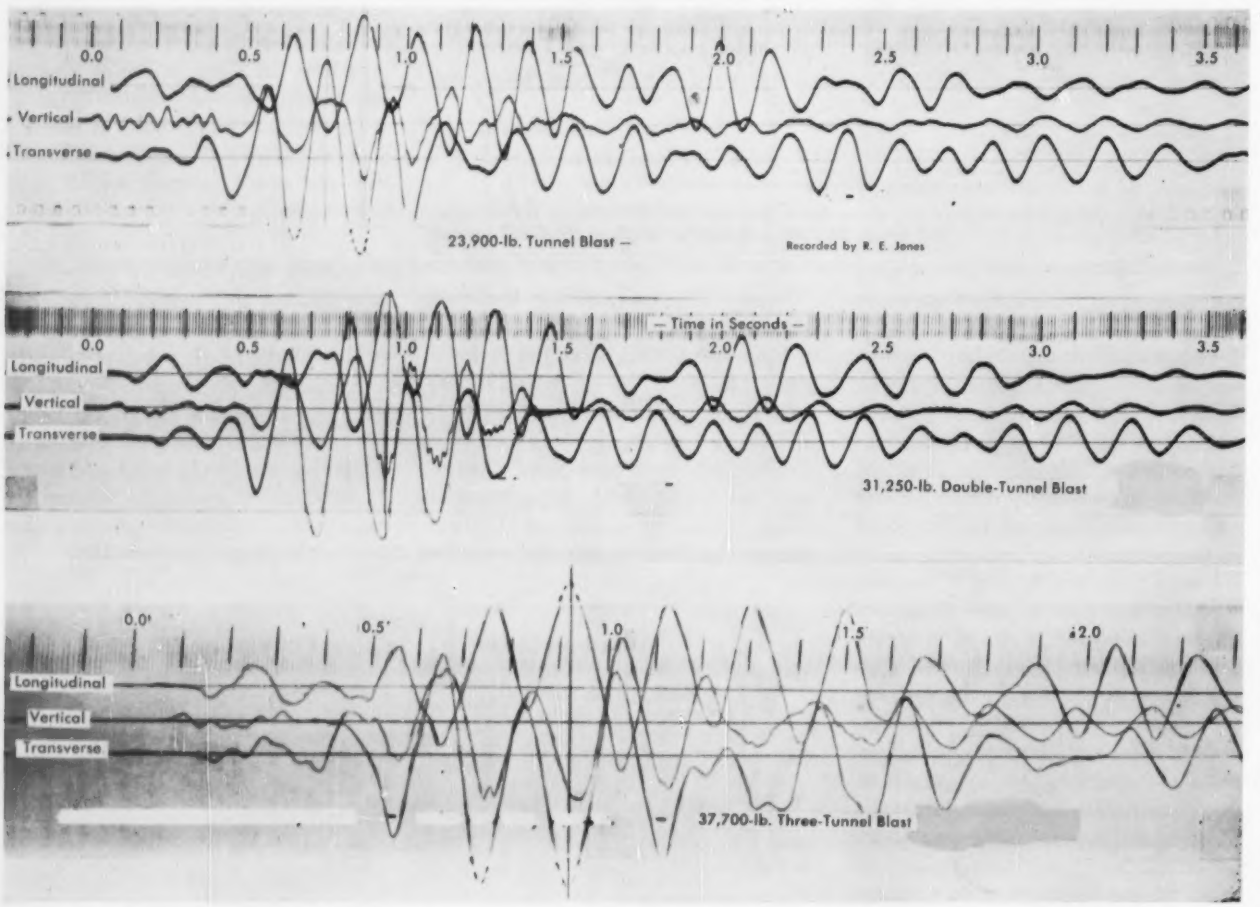


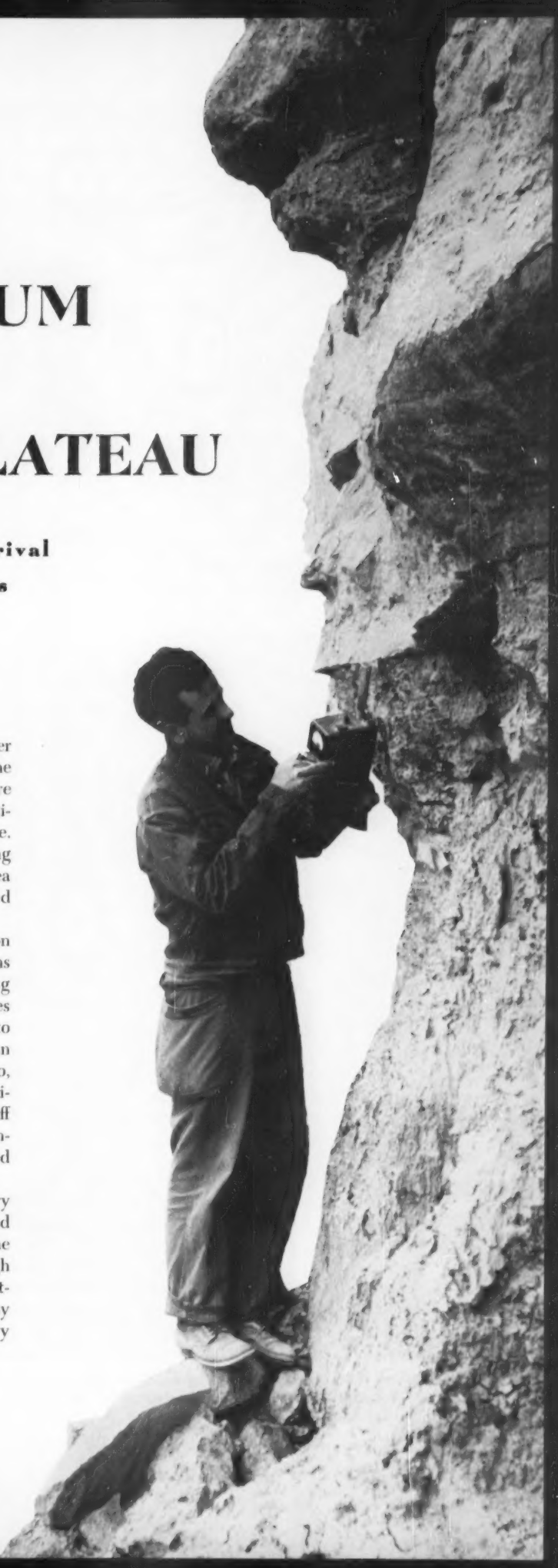
FIGURE 12: Records for a single tunnel blast as compared with a double and a triple delayed blast, as recorded on a Leet seismograph by Ranald Jones.

MINING URANIUM IN THE COLORADO PLATEAU

Activities in a 65,000-square mile area rival the fabulous California gold-rush days

CHARLES F. THOMAS*

PART I



WITHIN a circular area approximately 350 miles in diameter projected around Four Corners, that point common to the states of Colorado, Utah, New Mexico, and Arizona, there is more mining excitement and activity than would be stirred up on a sensitive Geiger counter by a near specimen of high-grade uranium ore. For it is uranium in apparently unlimited quantities that is bringing a rush of individuals and capital into the Colorado Plateau area that promises to surpass the wildest days of the much-publicized California gold rush in 1849.

Actually, the Colorado Plateau is misnamed, for it is a region marked by the deep canyons of the Colorado River whose depths lay but a few hundred feet above sea level, to scenic peaks rising 13,000 ft. or more. Between these extremes are 65,000 square miles of erosion, desolation, and loneliness. Yet it is thought by many to be more weirdly beautiful than any other part of the American continent. For centuries, it has been the homeland of the Navajo, Hopi, and Ute Indians. The remains of a vast, widespread civilization are found throughout the colorful canyons where the cliff dwellers' ruins stand. Unnumbered thousands of people once inhabited the ruins now found on the pinon- and juniper-crested ridges of the increasingly popular area.

Cardenas, under orders from Coronado to explore the territory in 1540, was the first white man to view the twisting canyons and the "Goosenecks" of the San Juan River. Two Spanish priests, the Reverend Fathers Escalante and Dominguez, traveled through and around the entire region on a hectic six months' journey, starting at Sante Fe in midsummer 1776. Father Escalante noted many of the strange and perplexing geological features of the territory in his famous diary.

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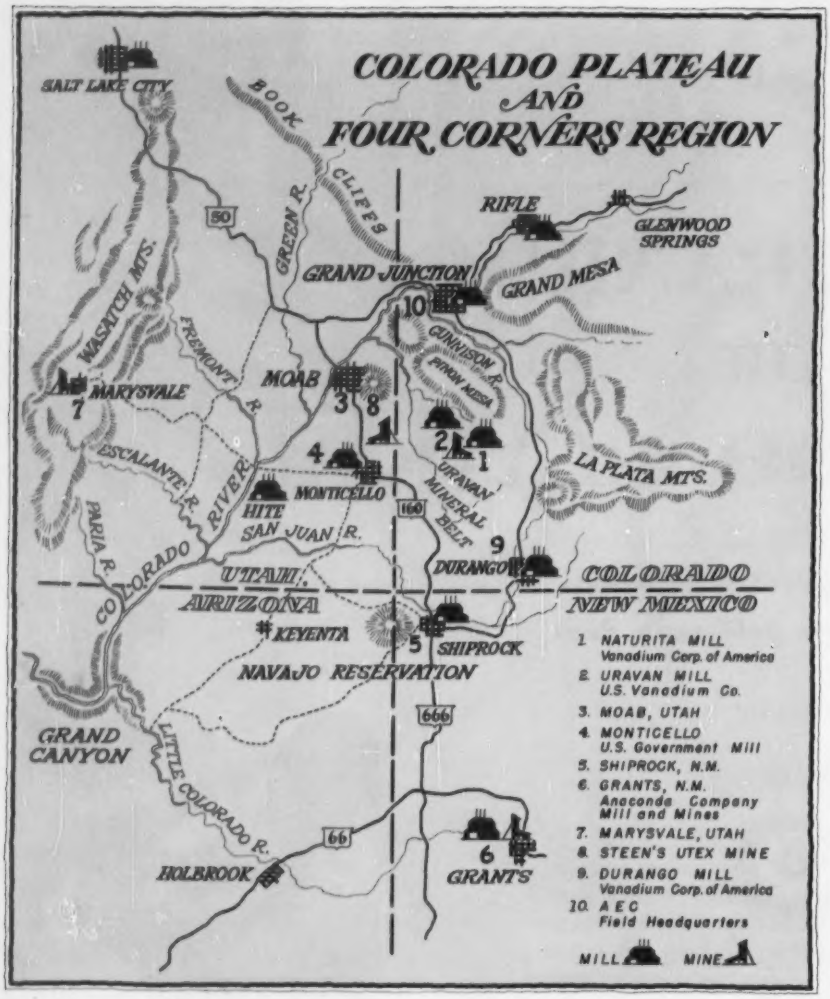


FOUR CORNERS AREA: Some of the principal mines and mills operating in the Four Corners area of the Colorado Plateau.

The Colorado Plateau

With the drift of civilization westward, the Colorado Plateau has remained as the last frontier of the wild and woolly West. Desolation Mesa, Outlaw Flats, Horsethief Canyon, Sew'em Up Gulch, and Disappointment Valley could furnish the settings for wild but true tales of their few scattered inhabitants.

It has been a paradise for geologists, artists, and photographers since the 1890's. For the geologist, nearly every page of the earth's history is opened, from the winding depths of Grand Canyon to the heights of sharp peaks that rise out of the waste land. For the artist and the photographer, it has the famous Natural Bridges, Arches National Monument, the Painted Desert, Monument Valley with its hundreds of spires, Mexican Hat, and thousands of other strangely eroded forms, caverns, gaudy cliffs, and deeply etched canyons, mostly unnamed and seldom seen or explored. Fossils and minerals of almost every kind are present.

The larger part of this apparently worthless territory has been good only for Indian reservations, scattered cattle ranches, or occasional dry farms. Springs and streams have been scarce — most of them evaporated in the fierce heat of the desert's summer sun. No railroads crossed the hills or followed the canyons. The Rio Grande Southern Railroad, which skirted the extreme eastern boundary of the area and served the San Juan mining region of Colorado in its heyday, was abandoned and removed a few years ago. The Denver and Rio Grande Western touches the northern edge of the circle, and the Sante Fe traverses the southern edge. Roads are scarce and unimproved, for the most part.

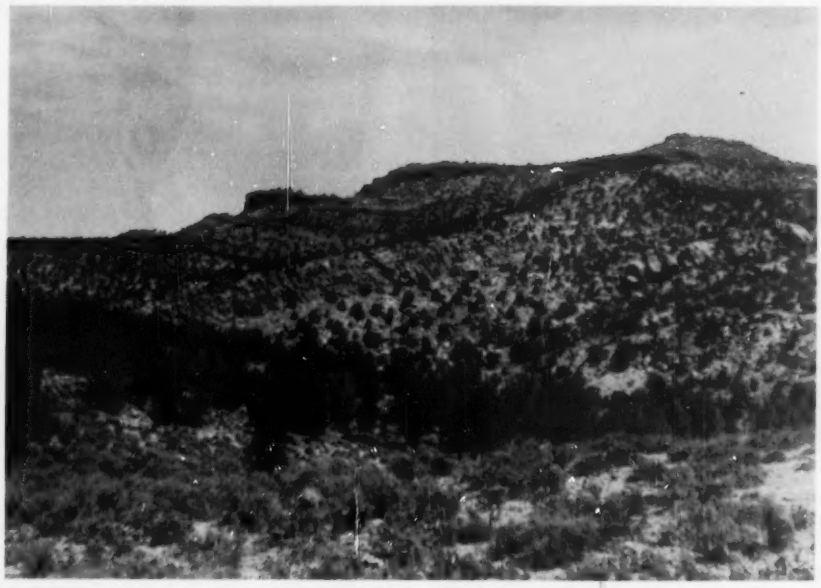
All soil has been eroded from hundreds of square miles, leaving barren rocky ridges and upthrust ledges of sandstone. There is little timber, except on the north slopes of the higher mountain ranges. The lower hills have sparse growths of sagebrush, juniper, and pinon, with pinon furnishing a staple food for the Navajos. The river banks have only a few scattered groves of cottonwoods.

Uranium

Today, as a result of the Government's participation in atomic nuclear studies, this heretofore practically worthless region has apparently become the greatest source of uranium on the American continent, if not in the world.

Uranium, now the most eagerly sought mineral element, was ignored for many years. Its value in earth's scheme of things was unknown. Pure uranium is a lustrous white metal, first recognized in 1789 as a component of pitchblende. It was named in honor of the planet Uranus, which had been discovered only a few years before. While uranium is found among more than 100 ores, its commonest occurrences are in pitchblende, carnotite, and uraninite. Pitchblende is, primarily, a bluish-black mineral found most plentifully in the Belgian Congo. Carnotite is a secondary canary-yellow mineral, found largely in the Colorado Plateau. Carnotite is a complex vanadate of potassium and uranium. Uraninite has been discovered recently in wide areas in the Colorado Plateau. Uranium has an atomic weight of 238.2; its atomic number is 92.

It is stated that one pound of uranium is equivalent in potential power to 1,300 tons of coal, with more energy than is contained in 350,000 gallons of gasoline, and with more horsepower than is generated from 2,500,000 kilowatt hours of electricity. The Atomic Energy Commission estimates that the energy potentially available in the world's reserves of available uranium is 20 to 25 times the energy contained in the world's combined reserves of oil, gas, and coal. Uranium and thorium,



BROKEN SANDSTONE FORMATIONS: A look at badly broken formations of Entrada, Morrison, and Dakota sandstone in a section of the plateau west of Redvale, Colorado.

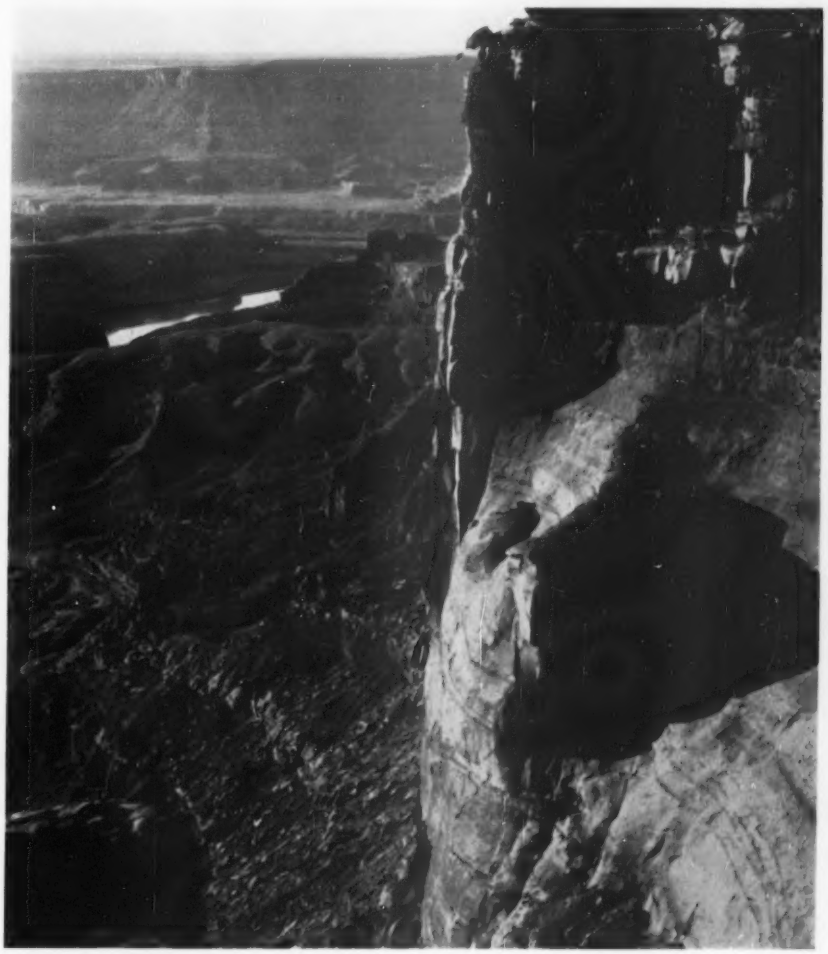
another radioactive mineral, are the most important of all substances in determining the ages of the geologic strata of the earth.

Radioactivity was discovered accidentally in 1896 by a Frenchman named Becquerel, who wrapped a photographic plate in black paper and placed on it a specimen of fluorescent salt. Development of the plate showed a distinct impression. His later experiments proved that all uranium minerals and salts produced the same effects. Occasionally, early-day prospectors tested samples of ore by the same method, placing a coin or a key between the unexposed plate and the ore sample being tested.

Prospecting

The day of the grizzled old prospector, with his pack outfit loaded on a slow-moving burro, is done. Today, prospecting is a scientific operation, but one in which any person who can borrow or buy a Geiger counter can engage in. And, when visiting the territory, it seems as though almost everyone is engaged in some form of prospecting. At times, the demand for Geiger counters has far exceeded the supply. In stores where they are displayed, clerks talk glibly of alpha, beta, and gamma rays. They refer to the different formations where uranium may be found with the manner of learned geologists. Many of them spend their weekends on the mesas and canyons in search of a deposit. A new term has been coined in the West, which refers to the lucky finder of such a deposit as a "uraniumaire." Tourists become excited when they reach some of the cities or towns close to the Plateau, often purchasing a Geiger counter and spending their vacations climbing over rock ledges or driving over lonesome stretches of poor roads that lead into spots where they hope to strike it rich.

Most of the areas where uranium is known to occur in Colorado and Utah have been explored thoroughly by the Atomic Energy Commission, the United States Geological Survey, the Bureau of Mines, by companies now engaged in exploiting deposits, and by prospectors who have roamed the hills through the years. Almost the entire region has been blanketed with claims.



DEAD HORSE POINT: Uranium mining operations are now under way on the lower benches of the canyon at Dead Horse Point on the Colorado River near Moab, Utah.

GREEN RIVER CANYON: The variable formations in Green River Canyon in southeastern Utah are primarily sandstone and shale. Carnotite and other uranium ores are also found in some of the measures.

"THE REEF": An aerial photograph of a spectacular geological upthrust in eroded areas west of Green River in southeastern Utah. Newly discovered ore-bearing strata of uranium lie to the south and west.

SAN JUAN "GOOSENECKS": In southeastern Utah, the area known as the San Juan Goosenecks is included in a vast flood-control program of the Bureau of Reclamation.

Today's Scientific Methods

Prospecting for uranium is not restricted to a slow, tedious method of tramping across ragged, broken terrain, in climbing up and down dangerous cliffs, or in poking the probe of a counter into crevices and holes in rocks. Modern science, aided by jeeps, automobiles, and airplanes, has developed methods far less laborious, and with more reasonable certainty of detection of high-grade deposits.

Airplanes or helicopters, equipped with scintillators, an extremely sensitive counter attached to the underside of the aircraft, are flown over the areas being studied. Such aerial exploration requires that the aircraft be flown at the slowest speed and the lowest elevation compatible with safe flying. The scintillator is said to detect deposits of a few feet in depth to hundreds of feet, depending on the radioactivity of the overburden and the size and quality of the ore body. The scintillator is also used in automobiles for observations along roads and highways.

In 1953, the Atomic Energy Commission had six planes in operation. Recently, this number was increased to ten. Many private planes are used throughout the area, for prospecting, freight hauling, photography, and for rapid transportation.

Carnotite

In the 1890's, high-grade carnotite deposits in Colorado and Utah were mined for their radium content. The radium used by Madame Curie and her husband in their famous discoveries was obtained from Colorado. Activities were expanded during the early 1900's because of an irregular demand for vanadium, for use as a ferro-alloy in steel manufacture. Little attention was given to uranium.

In the early years, all of the carnotite obtained was mined in the Morrison formation, a stratum of common occurrence in the West. It lays in the upper Jurassic period. In Colorado, New Mexico, and Utah the formation is readily recognized because of its proximity to the spectacular "Slick Rock" or layer of massive sandstone several hundred feet in thickness on which it and underlaying strata rest.

Because of the easily recognized colors generally occurring in carnotite

deposits, little else was required by the early-day prospector. Geiger counters had not been invented and it was not believed that radioactive ores occurred in other strata. The Atomic Energy Commission reports that commercial production of uranium has been realized from 18 different formations. Naturally, this report has greatly widened the field of recovery.

Indications are that all of the larger mining companies in the nation today are either prospecting actively in the area or have acquired claims which they are preparing to mine. In addition, hundreds of new companies have been organized and are building roads, drilling holes for exploration and testing, sinking shafts to ore deposits, or otherwise moving toward active production of uranium.

All of this activity has been brought about by the United States Government through the Atomic Energy Commission, with the latter actively sponsoring a program to provide ever-increasing reserves of uranium.

The AEC Program

The overall program of the Raw Metals Division of the Atomic Energy Commission is widespread. In April, 1948, headquarters were established in Grand Junction, Colorado. The United States Geological Survey is working closely with the Commission under a contract. The Bureau of Mines is also assisting in the program. Every facility of the three groups is made available to anyone interested. Complete information, with the exception of production data, is supplied. While the AEC does not engage in any mining activity, it covers all operating steps from prospecting to production, and offers aid to any individual or concern interested in uranium production. Exploratory work during the past three years has been extensive and the two Government groups have studied, surveyed, and mapped many wide areas of hard-to-reach mountain and canyon country.

As a coordinating agency, the AEC is performing an unusual service for the atomic program and the mining industry. Its program has awakened the West to the resources of the Colorado Plateau and to the potentials within the region. The apparently unlimited domestic supplies of the strategic mineral make for a much greater feeling of security for the forces experimenting with and studying uses of uranium for national protection as well as for peaceful uses.

WEST OF MOAB: A geologist-prospector with a Geiger counter tests for uranium in the mountainous regions of the San Rafael Swell country west of Moab, Utah.

The important aspect of the overall program is the reliance on private enterprise for the development and production of uranium. Figures recently released by the AEC indicate the immensity of the program – more than 150,000 persons are working on atomic energy projects. This number includes the personnel of the AEC and its engineering construction laboratories, and operating contractors. In all probability, several hundred thousand more are employed indirectly by firms that furnish supplies or services to the AEC.

Guaranteed Prices

To stimulate production of uranium, the Atomic Energy Commission, by an act of Congress in April, 1948, established a guaranteed 10-year schedule of prices for domestic U_3O_8 (uranium oxide) or mechanical concentrates. These minimum prices range from $1.50 a lb. for 0.10 per cent ore to $3.50 a lb. for ores assaying 0.20 per cent or more. The cost of refining such ores or concentrates to standards of purity required for the Commission's operations is deducted from the amounts paid to the producer.

Under an amendment passed October 5, 1953, the same schedule of guaranteed prices for uranium-bearing carnotite ores was extended to March 31, 1962.

(To be continued)

(Continued from page 147)

(M.R.D.) of ground vibration from 16 thousandths of an inch to 11 thousandths. But, increasing the amount of dynamite per yard in ten holes allowed the detonation of a total of 52,100 lb. with a maximum vibration amplitude of only 7 thousandths of an inch at the same recording location. The 52,100-lb. blast resulted in good digging; the 40,000-lb. blast was hard digging and left a lot of toe at the bottom of the face; the two-hole blast produced blocky material. The respective loading factors per cu. yd. were 1.01, 0.90, and 0.85.

Wagon-drill Delay Firing — Vibration Frequency Effects

As can be seen from an expression for energy ratio, such as E. R. = 10.8 f^2A^2, where f is frequency and A is amplitude in inches, the quantity is quite sensitive to changes in the frequency.

In general, large amounts of total explosive and large amounts per delay interval tend to set up vibrations with lower frequencies. Another factor affecting frequency was observed recently in a quarry firing wagon-drill holes on a benched face. It is illustrated by the two records of Figure 11, for which data are given in Table II.

The significant feature illustrated by Figure 11 and Table II is that, with all other conditions essentially similar, the blast at the top of the face (top record of Figure 11) produced vibrations with more energy in higher frequencies than the blast at the bottom of the face. An amplitude of 0.0041 in. at 75 cycles per second represented over five times the energy ratio of 0.0049 in. at 33 cycles per second, and over 75 times the energy ratio of 0.0076 in. at 5 cycles per second.

This demonstrates in one form the general principle that where larger volumes of rock are involved in the layout of a shot, lower frequencies carry most of the energy. Vibrations from the blast at the bottom of the face had to do extra work in moving the 120 ft. of material between the blast and ground surface as compared with the work done by vibrations from the blast at the top of the face. Motion ultimately established in the surface was lower in frequency and in energy.

Blasting Coyote Tunnels With Short-Period Detonators

Limited experiments in attempts to interpose short-period delay detonators in the firing of two or more coyote tunnels have not led to conclusive results. In view of the mechanism by which delay firing appears to reduce vibrations in well-drill shooting, a 20- to 25-millisecond delay between coyote tunnels 30 ft. apart at their closest points, but 60 to 70 ft. across each "T", should have no more than a limited effect in reducing vibrations. In practice, however, the delay detonation of dynamite charges in coyote tunnels seems to be more effective than predicted.

Figure 12 shows records from the blasts tabulated in Table III.

Table III and Figure 12 illustrate the conflicting features in the results of delay firing in coyote tunnel blasts. The vibrations from a two-tunnel blast were greater than from a one-tunnel blast although each of the two-tunnel blasts was loaded with less explosives than the single tunnel. On the other hand, the vibrations were not greater in anything like proportion to the increase in total explosives – 23,900 lb. to 31,250 lb., but 0.0327 in. to 0.0365 in. The three-tunnel blast, with the greatest total explosives, produced vibrations of intermediate magnitude. Actually, reduced to energy ratio, the vibrations were not significantly different for any of the three blasts of Figure 12, although the total amount of explosives was 58 per cent greater in the three-tunnel blast than that consumed in the one-tunnel blast.

TABLE III
DATA FOR COYOTE TUNNEL BLASTS WHICH PRODUCED THE VIBRATIONS SHOWN IN FIGURE 12

Top Record	Tunnel – 23,900 lb. Maximum Resultant Displacement = 0.0327 in.	
Middle Record	Tunnel 1 – 16,100 lb. Delay 0.040 sec.	Total 31,250 lb.
	Tunnel 2 – 15,150 lb. Maximum Resultant Displacement = 0.0365 in.	
Bottom Record	Tunnel 1 – 17,100 lb. Delay 0.020 sec.	
	Tunnel 2 – 14,000 lb. Delay 0.020 sec.	Total 37,700 lb.
	Tunnel 3 – 6,600 lb. Maximum Resultant Displacement = 0.0350 in.	

Seismograph at same location for each recording

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Many cancers can be cured, but only if properly treated *before* they have begun to spread or "colonize" in other parts of the body.

For *any* information about cancer just call the American Cancer Society or write to "Cancer" in care of your local Post Office.

American Cancer Society

POTASH

(Continued from page 141)

Following close behind PCA was International Minerals & Chemicals Corporation, which started its first shaft in the fall of 1936. It was able to turn out refined potash by October of 1940.

For several years, including all the period of World War II, when more potash than ever was needed for the production of food and fiber, these three pioneer operators were the only ones in the Carlsbad Basin. The heavy demand for potash in the postwar years interested other concerns. Early in 1952, Duval Sulphur & Potash Company came into production with a new mine and refinery. Later in that same year, Southwest Potash Company brought its mine and plant to the production stage.

The five operating companies have properties which are valued at $80,000,000 and a current crude-ore production of 8,000,000 tons a year.

Based on figures announced by Southwest Potash Company, the latest to get into production, it now costs at least $10,000,000 to sink a shaft and set up the necessary plant units. Despite this cost and the threat of a surplus of potash, two other organizations have indicated that they may go into production. They are the Freeport Sulphur Company and the National Farmers Union, the latter with headquarters in Denver. Each has made extensive core tests and found adequate deposits of potash.

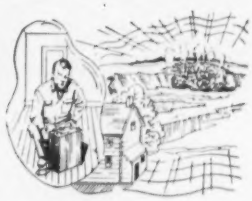
Two Million Tons a Year

The potash industry has grown at a pace so rapid as to be almost unbelievable. In 1939, deliveries in North America were under 400,000 tons. Production reached the 1,000,000-ton mark in 1947, and came close to 2,000,000 tons last year. Only in 1949 was the steady upward surge of deliveries interrupted. This was caused by a 73-day work stoppage, which closed all mines and plants in the Carlsbad Potash Basin.

Deliveries for agricultural purposes in the continental United States for 1953 were 1,663,242 tons K_2O, an increase of 70,662 tons over the previous year. However, production at Carlsbad went up by a much greater percentage. Canada received 72,501 tons of potash last year; Cuba, 4,509 tons; Puerto Rico, 16,699 tons; and Hawaii, 19,437 tons. Exports to other countries amounted to 1,742 tons.

It has taken lots of courage, know-how (or learn-how), and money to develop the American potash industry. Estimates of the reserves in the Carlsbad Basin indicate that they are sufficient to last at least 100 years. But the full extent of the Permian formations has not as yet been determined.

VIBRATION TROUBLES?



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INDUSTRIAL SEISMOLOGY

VIBRATION SURVEYS — BLASTING EFFECTS ANALYSIS

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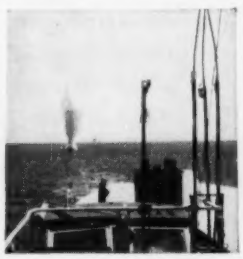
Another important Hercules seismic development is Spiralok®—the rigid dynamite cartridge assembly that simplifies and speeds up the preparation and loading of charges.

Hercules has been developing and manufacturing specialized types of explosives for over forty years, and at the same time building up service facilities to expedite their use in seismic exploration, coal mining, metal mining, quarrying, and construction. We welcome your inquiries.



Explosives Department

HERCULES POWDER COMPANY

INCORPORATED

990 King St., Wilmington 99, Delaware

Birmingham, Ala.; Chicago, Ill.; Duluth, Minn.; Hazleton, Pa.; Joplin, Mo.; Los Angeles, Cal.; New York, N. Y.; Pittsburgh, Pa.; Salt Lake City, Utah; San Francisco, Cal.

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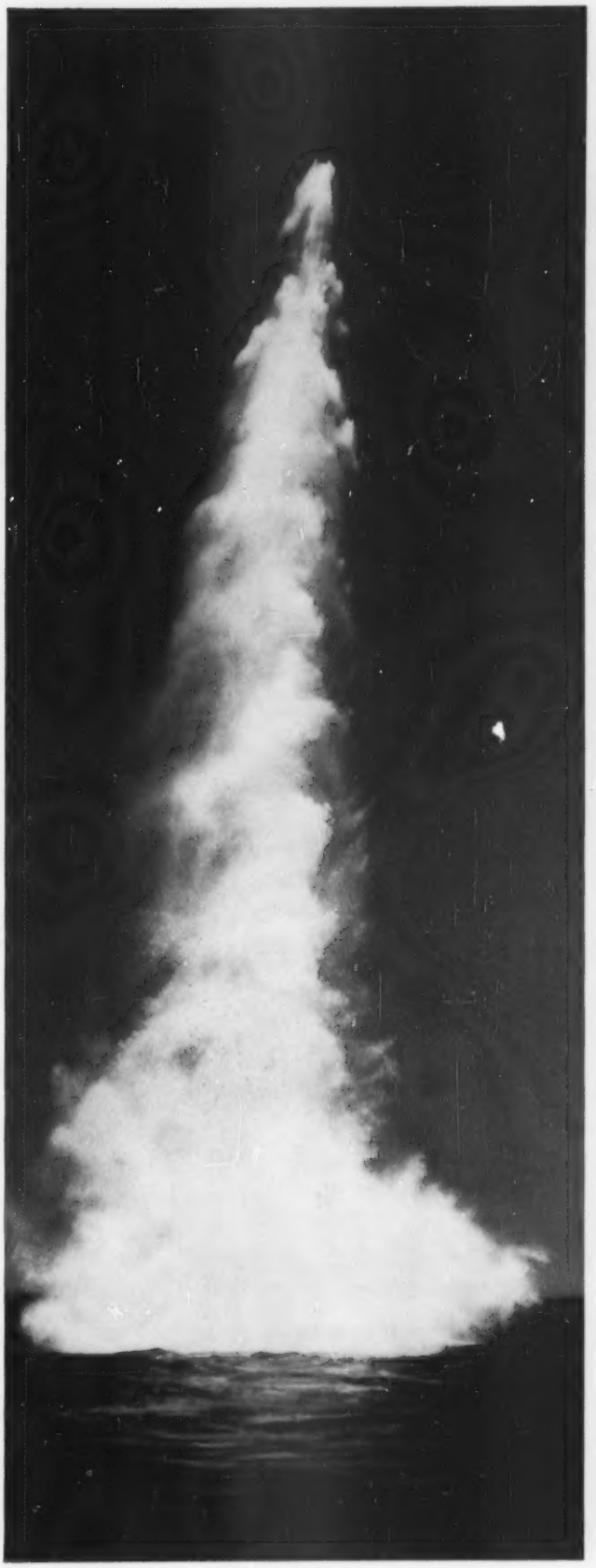
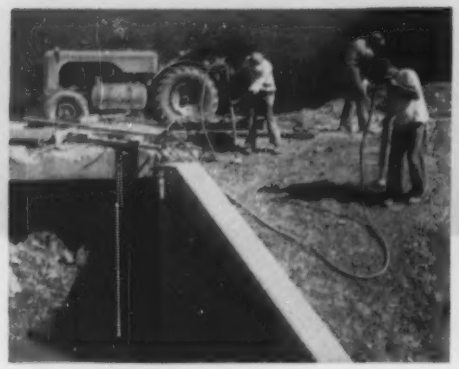


Tamping — Here's a Le Roi-CLEVELAND back-fill tamper air-powered by Tractair, that gives you faster, easier tamping, better compaction, lower costs. This example shows how Tractair teams up with Le Roi-CLEVELAND Air Tools to save time, work, money.



Cutting asphalt pavement — with a Tractair-powered Le Roi-CLEVELAND paving breaker. Note, Tractair in background is equipped with a sweeping attachment. This is just another of many ways that Tractair can save you money.

Drilling trench — Easy holding Le Roi-CLEVELAND sinkers provide the fastest way of drilling rock. The air-power source is a Tractair, equipped with a front-end loader. Tractair is extremely mobile. It has a low center of gravity. It takes money-saving air power anywhere.

LE ROI TRACTAIR

...the 10 in 1 machine that does 10 basic jobs to save you money

It holds down your investment in special equipment

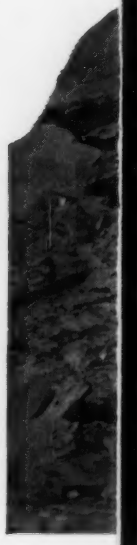
Because Tractair is a combination 35-hp wheel tractor and 105-cfm air compressor, it is extremely versatile.

It lets you take air power wherever you want it — air power for drilling rock, tamping fill, breaking concrete, driving spikes and form pins, or pumping water.

When it is equipped with attachments, you get added usefulness. You can load, back-fill, dig, sweep or hoist.

Although Tractair was pioneered and developed by Le Roi Company to do 10 basic jobs, its money-saving usefulness on costly, nuisance-type work is limited only by the user's imagination.

If you want to cut costs, get Tractair. Call your Le Roi dealer for a demonstration, or write us for further information.



LE ROI GIVES YOU MORE FOR YOUR MONEY

More Utility!
More Profits!

Loading — Tractair takes air power practically everywhere, yet it can be used for a wide variety of other jobs. Its front-end loading attachment, for example, has 8 accessories that interchange easily, so that Tractair can load, lift, back-fill, plow, etc.

Tractair with Mobildrill — Mobildrill is a lightweight wagon-drill attachment for Tractair. It gives you unusual mobility — one man can drill holes at any angle and any elevation up to 12 feet. Swinging boom permits drilling 4-6 holes of a pattern from one spot.

Compressors
Rock Drills
Tractair
Engines . . .

LE ROI COMPANY

Milwaukee 14, Wisconsin

A Subsidiary of Westinghouse Air Brake Co.

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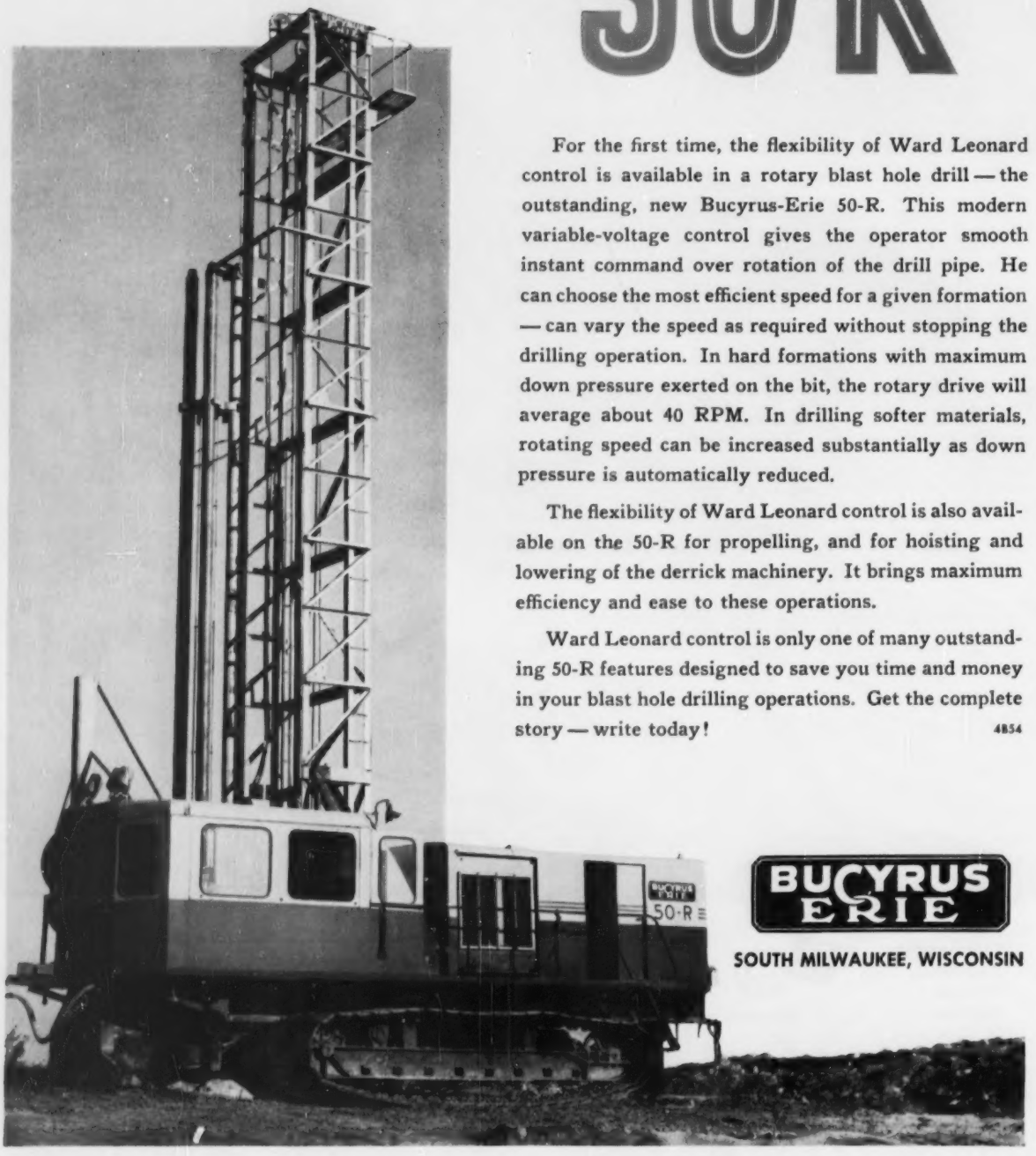
Your Choice of Drilling Speeds for Maximum Footage

BUCYRUS-ERIE 50-R



For the first time, the flexibility of Ward Leonard control is available in a rotary blast hole drill — the outstanding, new Bucyrus-Erie 50-R. This modern variable-voltage control gives the operator smooth instant command over rotation of the drill pipe. He can choose the most efficient speed for a given formation — can vary the speed as required without stopping the drilling operation. In hard formations with maximum down pressure exerted on the bit, the rotary drive will average about 40 RPM. In drilling softer materials, rotating speed can be increased substantially as down pressure is automatically reduced.

The flexibility of Ward Leonard control is also available on the 50-R for propelling, and for hoisting and lowering of the derrick machinery. It brings maximum efficiency and ease to these operations.

Ward Leonard control is only one of many outstanding 50-R features designed to save you time and money in your blast hole drilling operations. Get the complete story — write today! 4854

BUCYRUS ERIE

SOUTH MILWAUKEE, WISCONSIN

GEORGE M. BREWSTER & SON, Inc.

uses GYRO-FLO 600's

to help move 900,000 yards of rock

These four 600 cfm Gyro-Flo portables supply air power for operating up to eleven I-R wagon drills on this job. Air from the receiver is piped 700 to 800 feet to the drilling site through a 6" line. In left foreground is an I-R air powered Jackbit grinder.

Big job in a hurry. That's the fabulous N. Y. Thruway —a non-stop, high-speed highway from New York City to Buffalo, scheduled for completion in 1954.

To George M. Brewster & Son, Inc., sub-contractor for all rock work on the 7½ mile stretch from Kingston to Whiteport, goes the job of excavating an estimated 900,000 cubic yards of rock in record time. And this project is already well under way—with the help of Gyro-Flo portable compressors and I-R rock drill equipment.

The Gyro-Flo rotary sliding-vane compressor speeds drilling operations by delivering an abundant supply of air, at constant pressure, with the most dependable, trouble-free performance ever obtainable in a portable unit. That's because the Gyro-Flo has no valves, pistons, rings, rods or clutches to wear out, adjust or replace. It delivers oil-free air at temperatures that never exceed 200° F. And pressure is controlled closely and smoothly all the way from 0 to 100% capacity.

Now available in 125, 210, 315 and 600 cfm sizes, Gyro-Flo portables offer a new high in air power efficiency for practically any job. For the complete story, contact your nearest Ingersoll-Rand distributor or branch office.

2-28

Above are four of the FM-2 wagon drills supplied by the Gyro-Flo compressors shown at the top. Each drill is equipped with an I-R air hoist to facilitate movement of the drill carriage on the steep slopes.

Brewster also uses three self-contained, self-powered and self-propelled I-R Quarry-masters for deep-hole drilling.

Ingersoll-Rand

11 Broadway, New York 4, N. Y.

CONTRACTORS' COMBINATION

COMPRESSORS
ROCK DRILLS
AIR TOOLS
TURBO BLOWERS
CONDENSERS
CENTRIFUGAL PUMPS
DIESEL AND GAS ENGINES

IMPOSSIBLE WITHOUT EXPLOSIVES

120 million tons of iron ore, it is estimated, were mined in open pits and underground operations last year. This photograph shows some of the highly mechanized operations which make such huge production possible.

But before the ore can be dug, millions of pounds of explosives are used to break it loose from working faces, to assure easy shovel digging and rapid transportation of the ore to the crushing and washing plants.

The manufacture of explosives and the knowledge of their efficient and economical use have been Hercules business for 40 years. During this time we have studied the varying conditions under which explosives are used and have pioneered in developing the right types of explosives for industrial needs. Hercules explosives and services assure economical and efficient blasting not only in metal mining, but in coal mining, quarrying, construction—in fact, wherever explosives are used.

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